GENERAL BOARD OF HEALTH.

REPORT

ON THE

SUPPLY OF WATER

TO

THE METROPOLIS.

APPENDIX No. II.

ENGINEERING REPORTS AND EVIDENCE.

Presented to both Houses of Parliament by Command of Her Majesty.

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CONTENTS.

	Page.
Mr. Austin	3
Mr. Rawlinson	15
Mr. Rammell	21
Mr. Hocking	25
Mr. Quick	28
Mr. Mylne	42
Capt. Vetch	47
Mr. Henry Marten	61
Mr. John Roe	74
Mr. Stirrat	77
Mr. Gale	87
Mr. Frederick Braithwaite	93
Mr. Donaldson	99
Mr. Lovick	103
Mr. John Grant	134
Mr. E. Cresy, Jun.	150
Mr. E. Gotto	156
Mr. John Morris	180
Mr. J. Medworth	183
Mr. William Baddeley	194
Viscount Morpeth's Charge to the Jury (April 6, 1848)	199

LIST OF PLANS, ETC.

Plan No. 1	*to face p.* 91
,, Nos. 2, 3, 4, 5	,, 92
Analysis of 17 Samples of Water	,, 93
Table showing the decline of, and the effect of pumping on the Water in the Sand-spring underlying the blue and plastic clays in London	96
Diagram showing the fall of Water in the Sand-spring underlying the blue and plastic clays under London	96
Hydraulic experiments, Tables A. and B.	104
Drainage of Courts.—Tower Hamlets District	108
Tubular system of Drainage.—Poplar District	108
Plan of combined back Drainage—Orchard-street, Poplar	108
Drainage of Courts.—Westminster District	116
Transverse section of Sewers	132
Diagrams illustrative of the flux and reflux of the Tidal Waters in the river Thames on a float discharged at the periods of High and Low Water	132
Plans (Nos. 1, 2, 3, 4) of Drainage of part of Surrey and Kent District	140
Plan of public Water-closet	173

ENGINEERING REPORTS.

STATEMENT of the various SCHEMES proposed, and laid before the GENERAL BOARD OF HEALTH, for the improvement of the SUPPLY of WATER to the METROPOLIS.

To the General Board of Health.

MY LORDS AND GENTLEMEN,

IN accordance with your instructions that I should examine the various schemes that have been brought to your notice for the improvement of the supply of water to the Metropolis, and lay before you a general description of the whole, I have the honour to present the following statement. Mr. Austin.

They are twenty-five in number. Eleven of these consist of plans for bringing the supplies directly from various parts of the river Thames between Twickenham and Mapledurham; seven of the propositions are for supplies from various tributaries of the Thames; three are for supplies from springs, and four from shafts, or so called "artesian wells," sunk into the chalk of the London Basin. Ten of these schemes are or have been represented by Companies, or have emanated from engineers officially engaged, and the majority of these have been from time to time before the public in printed descriptions and prospectuses.

It would exceed my instructions to enter here upon any enumeration or historical record of the many plans which have been brought forward in former times, or to advert to the proceedings which took place before the Committee of Inquiry in 1828; but before entering upon a description of the plans immediately before the Board, I would beg to notice those which were prepared by the eminent engineer, Mr. Telford, in 1834, and which were the result of that inquiry; not because these plans are now again brought forward or represented, but because considerable attention has from time to time been directed to them, and because the inquiry into the means of improving the supply of water to the metropolis, may be said to be up to the present date nearly in the same position in which it was then left.

Mr. Telford's investigations were undertaken in consequence of directions received by him from the Lords Commissioners of Her Majesty's Treasury, to report "in what manner the metropolis can be supplied with pure water;" complaints having then been urged against the supplies from the river Thames, and the Committee of Inquiry having reported that they ought to be derived from other sources.

Mr. Telford states in his Report,—"The water of the river Thames being strongly objected to by the inhabitants of this great city, and also condemned in the Report of the Commissioners of

Mr. Austin. Water Inquiry (see Report 27th April, 1828, p. 11), in consequence of the impurities with which it is contaminated; I therefore perambulated the district on each side of the valley of the Thames, and examined the streams which fall into that river in the vicinity of London." The result of this investigation was the plan to bring water from the river Verulam for the supply of the districts on the north side of the river Thames, and from the river Wandle for the supply of the districts on the south side.

A reservoir was to be constructed at the Verulam, near Watford, whence a covered double aqueduct was to convey the water to a service reservoir on Primrose-hill, a distance of upwards of 15 miles, from which the distribution was to be made by the existing Companies, the Grand Junction, West Middlesex, and Chelsea. The estimate of cost of the works was 785,965*l.* 11*s.* 6*d.*

From the Wandle at Beddington, near Croydon, a covered aqueduct of similar character was to convey the water to a reservoir on Clapham common, a distance of upwards of six miles, whence it was to be distributed by the Lambeth, South London, and Southwark Companies. The estimate of cost of the works was 391,875*l.* 4*s.* 11*d.*

From information obtained by the Commissioners of Inquiry in 1828, it appeared that the average daily supply of water afforded by the Grand Junction, West Middlesex, and Chelsea Companies on the north side of the river, was 6,810,000 gallons, or nearly 13 cubic feet per second; but in order to provide for the maximum demand in 1833, and for future increase, Mr. Telford proposed that 30 cubic feet per second should be obtained from the Verulam.

The average daily supply afforded by the Lambeth, South London, and Southwark Companies on the south side of the river was 2,964,000 gallons, or 5½ cubic feet per second, and Mr. Telford proposed to receive from the river Wandle 13 cubic feet per second.

The total quantity of water therefore proposed to be supplied to the metropolis at that time was 23,220,000 gallons per diem, to afford which the total estimate of cost of the works was 1,177,840*l.* 16*s.* 5*d.*

In 1840 Mr. Robert Stephenson made a report to the London and Westminster Water Works Company—at that time established for supplying the metropolis with water from springs in the chalk near Watford—in which after alluding to the unsatisfactory mode in which London was then supplied with water, he states,—" It is indeed surprising that, with the exception of the proposal to obtain the water by perforating the London clay, every project, including Mr. Telford's, should have contemplated using the water of streams which are all subject to be affected by the surface drainage of a more or less extensive tract of country, and consequently only a very few degrees better than that already in use;" and further

on he repeats,—"that it is scarcely to be wondered at that the Legislature should have delayed acting on Mr. Telford's plan, which combined these objections with a very large outlay, nor that a Company should still have found grounds for proposing artesian wells in preference to his suggestions." Mr. Austin.

With regard, however, to the artesian schemes referred to, and which are again brought before the public, Mr. Stephenson proceeds to give very conclusive reasons for insufficiency of supply from such a source.

No estimate of cost of the proposed plan of water supply from the chalk at Watford is given in Mr. Stephenson's report, it being mainly directed to show that the necessary supply for London could be obtained and conveyed from that source.

The plan thus proposed was in part revived during last year by the London (Watford) Spring Water Company, and a Bill introduced in the present session of Parliament for carrying it out. The plan of obtaining the supply appears to be virtually the same as that of Mr. Stephenson, but it is said to be "in part revived," because instead of the present scheme being intended for a complete metropolitan supply, it is only proposed now to bring in 8,000,000 gallons per day for the supply of the northern districts. It is proposed to raise the water from wells in the Bushey meadows, and conduct it through cast-iron pipes into reservoirs on Stanmore Heath, whence it is to be led to another reservoir at Child's Hill, near Hampstead, and from this the water would be conveyed to Oxford-street, or in any other convenient direction to London and Westminster. It is intended also to supply some suburban districts on the way.

The estimate of cost is 350,000*l.*

Two other schemes before Parliament during the present session were for obtaining new supplies directly from the Thames, one from near Henley, the other from near Mapledurham. For the first, notices were given by a Company in the previous session, but the Bill was lost on the second reading in the Commons. It was renewed in the present session with the proposition of its being managed by a metropolitan Commission. It is proposed that an open canal 40 feet wide and 10 feet deep, should convey the water from the Thames near Medmenham Abbey to West Drayton, thence a smaller open canal would extend to the river Brent, from which point two brick culverts of 10 feet diameter would convey the water to a reservoir at Hampstead, from which it is proposed to raise it by steam-power to another reservoir 250 feet above high water. The total distance is 33½ miles.

From the Thames to West Drayton 200 million gallons are proposed to be conveyed daily, whence 100 million gallons are to be brought to the metropolis by the Grand Junction Canal, for the purpose of flushing the sewers, and 100 millions to be conveyed by the proposed canal and culverts to Hampstead for the daily

Mr. Austin. supply to the inhabitants. The estimated cost of the works is 2,000,000*l.*

In the prospectus or exposition of the measures proposed to be taken by the promoters of the Mapledurham scheme, of which Messrs. Gordon and Liddell are the engineers, it is stated that—"There is no source of water within the Thames basin from which a supply sufficient for the wants of the metropolis can be obtained excepting the river Thames itself," and that "the Thames at Mapledurham lock has been proved to be purer than at any other point below its source." It is therefore proposed to bring 50 million gallons daily supply from the Thames at this point, and to convey it by an open canal for a distance of 4½ miles into four reservoirs at Caversham. The promoters state further that "the water of every spring in the Thames basin, and of every river flowing through it, is hard. Hard water is unfit for most domestic purposes." And therefore the proposed supply is to be submitted to Dr. Clark's process, and then raised by steam power and conveyed to London through three iron pipes 5 feet diameter, following the line of the Great Western Railway.

In addition to the 50 million gallons thus to be daily supplied, it is proposed that the supply of 12 to 13 million gallons afforded by the New River should be still available for sanitary purposes.

The cost of executing this scheme is estimated at 1,200,000*l.*

Mr. Quick, the engineer of the Vauxhall and Lambeth Company, and consulting engineer of the Grand Junction Company, has proposed to bring a complete supply of water for the metropolis from the Thames at Eel-pie Island, Twickenham, considering that there would be no advantage corresponding to the increased outlay to be obtained by taking it from any point higher up the river.

The arrangements proposed by him would deliver the water filtered to the distributing pipes of the present Companies, but would dispense with all the existing pumping establishments. The cost of the works for the daily distribution of 50 million gallons from this point, Mr. Quick estimates at 300,000*l.*

In 1846, the promoters of the proposed "Aqueduct Company," brought forward a scheme for the supply of water to the metropolis from the River Thames, near Amerton Bank, about a mile and a half south-east of Maidenhead, at which point, according to Mr. Hawksley's report, it may "be received and filtered in immense volume; that it may thence be conveyed by a properly constructed tunnel to a point immediately below Hampstead-hill; that it may then be raised by the action of powerful steam-engines into elevated reservoirs, and afterwards be distributed through the metropolis and its suburbs, by communications to be made, for the most part, with the works of the existing Companies."

Mr. Hawksley estimated that within twenty years the population of the metropolis would amount to three million persons, and that the future daily consumption of the whole metropolis may be

assumed at 75 million gallons; that the quantity which would still probably "be supplied from the existing works and machinery of such of the Companies as derive their supply from sources, the character of which is neither now nor hereafter likely to become unfit or objectionable," could not be taken at more than 25 million gallons, and "consequently that a demand upon the works of the intended Company, of not less than 50 *million gallons per day*, may be expected within the term for which provision is now proposed to be made." Mr. Austin.

In this scheme it was proposed to establish on the banks of the Thames near Bray, ten subsiding tanks of five acres each, and ten filter beds of two acres each. The tunnel or aqueduct to convey the water to Hampstead was to be of brick, 12½ feet in diameter, and here were to be ultimately established 12 engines of 250 horse power each, for raising the water into elevated reservoirs.

The total estimate of these works was 746,790*l.*

Mr. P. W. Barlow, the engineer to the South Eastern Railway Company, proposes to obtain the supply of water for the metropolis by the interception of the springs which issue from the chalk, and discharge into the River Thames along the North Kent district between Greenwich and Strood. Professor Ansted, in a report to the Directors of the Railway Company, states, "that there exists, at a moderate depth, a supply which is practically inexhaustible." In a further report he adds, "that the whole of the chalk between Erith and Gravesend is saturated with water, considerably above the level of low-water level, and that a very large supply, equivalent to several millions of gallons per day from these localities only might readily be intersected by a tunnel or number of bores, and is fully available without interference with existing interests."

Samples of this water taken from Charlton, Abbey Wood, Northfleet, and Strood, were submitted to Professor Brande for examination. The detailed analyses of these four samples (together with that of a sample from a well at the Bricklayers' Arms Station, which is a very different character of water, assimilating to that of the deep wells of London,) are given in a report by Professor Brande addressed to Mr. Barlow, from which it appears that their degrees of hardness range from 22·5 to 26·3. Mr. Barlow proposes to intercept this water by constructing a heading, or small tunnel, along the course of and underneath the line of the North Kent Railway, with borings every half mile, affording a supply of 100 million gallons per day.

The cost of the works for bringing the water to the railway terminus at Bricklayers' Arms, he estimates at 150,000*l.*

Mr. Rendel, the engineer, although he has proposed no specific plan for improved supplies of water to the Metropolis, expresses some opinions on the subject in a report recently issued on the proposed improvements of the river Lea navigation, which it ap-

r. Austin. pears desirable to include in this description. In alluding to the quantity of water delivered at Feilde's weir on that river, Mr. Rendel states:—

"It does not come within the scope of this report, limited as it is to the description and objects of the works shown on the plans now before Parliament, for the improvement, &c. of the navigation, to devise a plan for making this water available to the supply of London, or to discuss the mode of dealing with the several interests involved; but it is clear, that when the question of making such supply is fully gone into, as it assuredly will be ere long, advantages such as the Lea possesses cannot be neglected; particularly when it is remembered, that not only is the available quantity of water very large, and its quality excellent, but that the means by which it can be supplied are already in existence; I mean the New River, which is not more than 100 yards distant from Rye House, up to which Feilde's weir pond extends. But it will be said, that the New River is not a suitable channel for its conveyance to London, in a manner that will satisfy the consumer. It is no part of my duty to say how the course of the New River may be improved, to obviate such objections. I may, however, call your attention to the fact, that all the objections which apply to the New River in this respect, apply to any other open conduit, whilst the expense of removing them by suitable alterations, would not probably amount to the cost of purchasing the land of any new conduit.

"The river Lea being in my judgment the most eligible source from which to get the necessary additional supply of water for London, it appears to me that you, the only public body having a Parliamentary interest in the river, as trustees for the maintenance of its navigation, should take the initiative step, by acquiring, before any abstraction of the water is allowed, such powers as would enable you to place the public interest which you represent, in a safe condition, and also remove, as far as practicable, the consequences to the mill-owners. As the promoters of a measure of this kind, you, in your capacity as trustees, with no personal or pecuniary interest in the question, are in a condition to protect the private interests with which your public trust is associated; not certainly to the extent of depriving the metropolis of water which may be parted with, after other interests are protected, but by obtaining powers from Parliament that shall secure the navigation beyond all doubt, and at the same time provide a means of guaranteeing the mill interest on the river from loss of the water usefully available, without adequate compensation."

Captain Vetch, in his evidence, has laid before the Board, a comprehensive scheme for the supply of water to the metropolis from various sources. In alluding to the ratio of increase of the population of the metropolis, he states,—"I consider it a most important measure to secure all the best supplies of water that

can be obtained near London, before they be appropriated to other objects of minor importance." The supplies referred to appear to be the river Verulam, the Colne, the Gade, and the Chess, and the river Lea and other streams of that neighbourhood on the north side of the Thames, and those of the river Darenth, and the Mole, on the south side of the Thames. These waters Captain Vetch proposes to conduct to elevated reservoirs in the neighbourhood of the metropolis, chiefly by means of tunnels or adits in a direct course, affording a supply of 100 million gallons daily. No estimates of the proposed works are given. The proposed lines of aqueduct are marked on the accompanying map, and as Captain Vetch's views are set forth at length in his evidence, it will be unnecessary to enter more fully here into a description of the schemes presented by him. In referring, however, to the means of conducting the supplies from their sources, it may be useful to allude to the objections set forth in his evidence, to open tortuous channels, such as that of the New River Company. "Within the present century," Captain Vetch remarks, "great ingenuity and great expense have been applied by the New River Company, to correct the evils of the rude and vicious mode of conduit first adopted, and little more improvement can be effected in that direction, indeed such praiseworthy zeal would be better applied to change the system entirely; but probably the very great misapplication of funds and talents to perfect in detail what was defective in principle, may have served to protract the existing works in their primitive form to the exclusion of others more capable of meeting the demands of the day." **Mr. Austin.**

In referring to the river Verulam, Captain Vetch observes:—"It seems the more necessary to secure this source of supply for the public benefit, as its good qualities are too well known to allow it to remain long unfingered by some commercial Water Company." And, alluding to the Watford scheme already described, he adds:—"Indeed there is a Bill before Parliament this year, which proposes to appropriate the same, and to drive it up by steam-power to high reservoirs at Stanmore, Elmstree, Harrow, and Hampstead, for the supply of the outskirts and country villages; whereas it may flow by gravitation high enough for the wants of the great metropolis."

In referring to the Henley scheme now before Parliament and already described here, Captain Vetch observes:—"If for the sake of argument, it be admitted that the object of the promoters of this scheme is exclusively that of supplying London with water for domestic purposes, then all the objections I have stated to the conduit of the New River will equally apply to the open channel proposed for this scheme." In allusion to the Mapledurham as well as the Henley scheme, upon the question, "If the water were permitted to be taken from the Thames above the influence of the tides, where do you conceive it would be most convenient to

Mr. Austin. take it from?" Captain Vetch observes:-—"As near above Teddington Weir as local circumstances would permit," and gives his reasons for preferring that it should be abstracted from a point near Twickenham, and conveyed as proposed by Mr. Phillip Taylor in 1824, rather than from any higher point up the river.

Mr. J. P. Thompson's scheme, for which a Company has been formed, under the title of "the Wandle Water Company," is, according to their prospectus, intended "to furnish the inhabitants of the metropolis south of the Thames, and those of Brixton, Clapham, Dulwich, Norwood, Sydenham, Wandsworth, Putney, and other adjacent places, with a cheap, abundant, and constant supply of pure and wholesome water," obtained from the river Wandle. It includes a plan for the drainage of the whole of the towns and villages along its course from Croydon to the Thames at Wandsworth, so as to intercept the whole of the refuse which now discharges into the Wandle, and apply it to the enrichment of the land.

It is proposed "to take the water, in its unpolluted state, at Wandsworth, *after it has done its work for the mills,* and raise it to reservoirs on Wimbledon Common." With respect to quantity, it is stated that "the river Wandle, as proved by the most careful and scientific gauging, yields a minimum supply of upwards of 27 million gallons, and a maximum of upwards of 44 million gallons per diem."

The estimate of the cost of works is 250,000*l.*

A prospectus and report has been laid before the General Board of a Company which has been registered, having the title of "The London and Medway Double Service Fresh and Salt Waterworks Company, for obtaining a constant supply of pure water from the river Medway, and its tributaries, the rainfall of the Tunbridge and Holmsdale valleys, the river Darenth and the River Cray, all of them situate in the county of Kent. And for establishing a permanent salt-water sanitary service for the metropolis, by supplies of sea-water drawn from the estuary of the Medway."

The prospectus states that "the district to be supplied contains on a rough estimate, 100,000 houses, of which 60,000 are either partially or wholly unsupplied with water," and "in addition to its own independent labours, the Company will seek to supply the Lambeth, Southwark, and South London Water Companies, with pure soft water, in lieu of the hard unwholesome water which they are at present compelled to distribute." Further on it is stated, "that the London and Medway Company will enjoy a command of water sufficient for all the uses of a city twice the size of the existing metropolis."

It is proposed to collect the waters, at suitable points, in vast reservoirs, and to carry them by the line of the North Kent Railway, in four large main pipes, to Kidbrook, near Blackheath, whence it would be distributed by gravitation.

The principal objects of the "salt-water service" are stated to be "1st, The daily cleansing and purification of the streets; 2nd, Flushing the sewers and purification of the Thames; 3rd, Supply of public and private baths; 4th, Extinction of accidental fire." Mr. Austin.

No estimate of cost of any of the works is given, but the proposed capital of the Company is 400,000*l.*

The scheme for supplying the whole metropolis with water from "Artesian" wells sunk into the chalk of the London Basin, appears to have been advocated, for some time, by the promoters of a society, under the title of "The Metropolitan Water Supply Association; for establishing the whole water supply of London, and its suburban districts on a self-supporting principle, through the medium of one public institution, directly responsible to the inhabitants; and for insuring an abundant continuous supply of pure soft water to all classes throughout the metropolis."

No plans of the arrangements proposed for carrying out this scheme have been brought before the General Board, nor any statement of the quantities proposed, nor estimates of the cost of the works.

Having now briefly described the main features of the whole of the schemes for an improved supply of water, which have been more prominently brought forward, and have been for the most part represented by Companies, I shall proceed to notice in the same manner those suggestions which have been laid before the Board for the same object by their individual authors.

Mr. James Dean, of Tottenham, purposes to obtain the supply of water from the river Thames, between Kingston and Richmond, conveyed into reservoirs on the banks of the river, in the bottom of which reservoirs, should additional supplies be required, he proposes to sink shafts into the chalk, from which he entertains no doubt that any amount of water may be obtained. No estimates are given of the proposed plan.

Captain Hood, R.N., has laid before the Board a voluminous paper on the subject of the supply of water to the metropolis, and an extensive plan of the valley of the Thames, evidently the result of the devotion of very considerable time and personal labour to the subject. The main feature, however, of Captain Hood's propositions is, that it would be perfectly useless to go such a distance up the river Thames for the supply of water, as proposed either by the Henley or the Mapledurham scheme, when it could be equally well obtained from near Maidenhead.

Dr. Dowler lays a proposition before the Board for obtaining the supplies from the river Thames, just above Teddington locks.

Mr. Hardinge proposes the Thames at Staines.

Mr. H. H. Fulton purposes also to obtain the supplies from the River Thames at Staines, diverting from the river the sewage of the towns now discharging into it above that point. "This

r. Austin. plan," he states, "as compared with the Henley project, would shorten the length of the principal conduit by 18 miles, and occasion a saving more than equivalent to the expense of diverting the sewage from the whole of the river above Staines." It is proposed that the water should be brought in a close conduit, in the direction of the western road, to the north-west of London, where it should be raised to the heights required for distribution.

No estimates are given of the proposed works.

Mr. B. Denton proposes "to unite, by an open or covered channel, the surplus water of the Thames, *i. e.*, as much as may be required and attainable, after a due provision for navigation, with the water of the Colne, a little above Colnbrook, and by the course of that branch of the Colne, called the Queen's river, convey it to *Feltham*, at a point where the latter crosses the 'Windsor, Staines, and South-Western Railway,' at the summit of that line. The point from which it is proposed to take the water from the Thames is a little above Boulter's Lock." It is proposed to construct reservoirs adjacent to the railway, and carry the water "by pipes laid within the property of the South-Western Railway Company, to such points as it would be most convenient for diverting into courses of supply, or for raising to a higher level for high service." It is stated that 50 million gallons should be supplied daily from these sources, leaving other 50 millions to be supplied by the New River and East London Companies to their respective districts. No estimates of the cost of proposed works are given.

Mr. James Green proposes to obtain a supply of pure water from the Thames, without going so high up as to be beyond the tidal influence, by converting a part of the course of the river into a canal, and thus cutting off the impurities which at present contaminate the water.

Mr. William Baker proposes to conduct the waters of the river Chess, in Hertfordshire, to London, taking the supply at about a mile below the town of Chesham. He estimates that 25 million gallons per day may be obtained, which he believes to be double the quantity supplied by all the present Companies. The cost of the works is calculated at from 250,000*l.* to 300,000*l.*

Mr. T. H. Liberty proposes to make the Basingstoke canal available for the supply of water to the metropolis, receiving, in addition, certain springs at Frimley, which now flow under the canal for the use of mills. It is estimated that the canal holds 76 million gallons, which, with the addition of the springs referred to, Mr. Liberty conceives would keep up the supply. He calculates the cost at 465,000*l.*

Mr. W. Rae proposes to obtain the supplies from Artesian wells, a Company being formed in each parish for the purpose.

Mr. John Pym proposes to obtain the supply of water by sinking, "at a given distance from the Thames, on each side of

the river, a series of shafts, down to the chalk, say one or more every quarter of a mile, each shaft to have a canal or aqueduct communicating with the Thames, between high and low water-marks, through this aqueduct a stream would flow for a given period, twice every day, to fill these shafts, and ultimately fill the chalk basin. At a convenient distance from this descending shaft another shaft should be sunk, into which the filtered water would flow as in an inverted syphon, until it rose to near the level of the water in the Thames." Mr. Austin.

The plan proposed by Mr. F. F. Couch for obtaining the supplies is identical in principle with that of Mr. Pym.

In the foregoing description of the schemes which have been recently brought before the Board for the improvement of the metropolitan water supply, I have confined the statement to a mere description of the leading features of the plans, as set forth for the most part by the authors or promoters themselves. Several of the papers which accompany many of the promoters' proposals are mainly occupied in showing the impracticability of, or objections to, other of the plans which are rival to their own. It has not appeared to be necessary to remark upon these statements, or in fact to enter upon any comparison of the schemes set forth, to do which effectually would have required considerable time and a far greater amount of information than has been afforded. Although it will be obvious that several of the plans presented are of an impracticable character, and emanate from persons possessing no acquaintance with the subject, I have thought it right to mention the whole of the schemes that have been brought to the notice of the Board.

With reference to the amount of improvement over the present modes of supply, which appear to be offered by many of these proposed schemes, I would beg to offer one or two general remarks which occur upon an examination of their leading features.

As to improved sources of supply, and the promise of better qualities of water therefrom, it will be observed that twenty out of the twenty-five schemes enumerated propose still to obtain the supplies either from the river Thames itself, or those of its tributaries, the qualities of the water of which, in its original conditions, differ in a very immaterial degree. While the inherent objectionable qualities of these waters appear for the most part to have been overlooked, the great aim has been, from the time of Mr. Telford's plan to the present, to obtain a supply as free as possible from organic impurity, for which purpose several of the new schemes propose to obtain supplies of the same water as at present delivered, taken from higher up the river Thames or its tributaries, or to intercept the large amount of refuse which now discharges into them. With reference to the comparative quality of the water taken from the Thames at the highest point proposed, I would beg to direct attention to the report of Messrs. Brande,

Mr. Austin. Cooper and Taylor, addressed to the Directors of the Southwark and Vauxhall Water Works Company; and as to the objectionable qualities of the spring water from the chalk of the North Kent district, which may be said to be perfectly free from organic impurity, but yet totally unfit for domestic uses, I would also refer to Mr. Brande's analyses of these waters, already referred to.

Evidence has been laid before the Board on the qualities of the water from the deep wells in the chalk of the London basin. Upon the probability of obtaining supplies from this source to meet the consumption of the metropolis, the statements of Mr. Robert Stephenson and the evidence of Mr. Braithwaite may be consulted.

Instructions were early given by the Board for an examination of the waters of the valley of the Medway, the results of which have already been laid before them.

With regard to any proposed improvements in the Management of the water supply of the metropolis, it will be observed that the majority of the proposals consist of the introduction of additional Companies over the same fields of supply, or at the best, a substitution of one Company for another. Of the propositions which are not brought forward by Companies, two only enter upon the important question of management, and these propose the appointment of a separate parochial Commission for sole jurisdiction over the water supply.

In four other of the schemes only is any point made of improved modes of supply, and these recognise only the importance of a continuous over an intermittent system. In Mr. Quick's statements will, however, be found some judicious suggestions for at once affording a continuous supply to courts and blocks of tenements, which have already been put in operation with good effect, and which, as an intermediate course pending the establishment of complete measures, are well worthy of consideration.

While none of the schemes, with this exception, can be said to point to the extended improvements which appear to be so necessary in the modes of distribution and apparatus, or to that combination of works of water supply and drainage, of delivery of water to the house and the discharge from it, which all the sanitary inquiries have shown to be indispensable to the improvement of the healthful condition of town populations,—with regard to quantity, nearly the whole of the schemes, where the question of quantity is mentioned at all, propose to afford a far larger amount of water than is at present delivered. Although none point to the means of economizing the supplies, of preventing the present immense daily loss of water and the evils of this waste in the low districts, the quantities for the most part proposed would far exceed those which all the inquiries instituted by the Board have shown to be sufficient.

The results of the inquiries in which I had the honour to take

part, in conjunction with the Superintending Inspectors, as to whether the sand districts of Surrey would not afford adequate supplies of water of far superior quality to any that were pointed out in the schemes before the public, having from time to time been laid before the Board, in which all were agreed, it will be unnecessary to enter in this place on the points of comparison with the schemes here described; but I would beg to repeat, that the very short period that has of necessity been allowed for that examination, attended although it has been with such promising results, has in no way done justice to the subject. The view obtained has been also over a limited area only, no opportunity having been so far afforded us of extending the investigation over the more westerly parts of the district described by Mr. R. Austin, or the more southerly district of the sources of the Wey. It would be be most desirable that this extended examination should be made, as it may very materially enlarge the view of the capabilities of the district, and modify the calculations that have been made thereon. Mr. Austin.

I have the honour to be,
My Lords and Gentlemen,
Your very obedient servant,
HENRY AUSTIN.

REMARKS on the CROTON AQUEDUCT, New York; and on Ancient and Modern Works of Water Supply. By ROBERT RAWLINSON, Esq., Civil Engineer, Superintending Inspector. Mr. Rawlinson.

In 1774, the population of New York was 22,000.

Cost of first Water-works at New York.

Expenses	£. 2,500
Land and materials	8,850
Total .	11,350

A reservoir was formed, and a well was sunk on the east line of Broadway. But the war of the Revolution, which broke out in 1775, retarded the completion of this work, and the town appears quickly to have outgrown it.

In 1798, the Bronx river was proposed; this scheme was not, however, matured. But the same year, the Manhattan Company was incorporated, with powers to supply the citizens with pure and wholesome water. They rejected all foreign sources, and sunk wells within the city limits. The quantity of the water obtained was deficient, and the quality most objectionable. The scheme proved unsatisfactory.

In March, 1822, the mayor brought the deficient state of the water supply before the Council, and a Committee was appointed to consider the subject. The principal source of the Bronx river was again sug-

Mr. Rawlinson.

gested. Yellow fever prevailed in the city during this summer, which, no doubt, quickened the civic desire to obtain some better supply of water. The engineer appointed to examine the district, and report on the contemplated scheme, seems to have been delayed, as the report was not handed in before January, 1824. 3,600,000 gallons of water were to be furnished at an estimated cost of 1,949,542 dollars. In the following year, a Company was incorporated, styled the "New York Waterworks Company." Water was to be taken from the Bronx at Underhill's bridge; from where the engineer reported that 9,000,000 gallons could be obtained at a cost not exceeding 1,450,000 dollars. The Sharon Canal Company had, however, in the meantime, forestalled the Waterworks Company, and defeated this project, so that in 1827 this Waterworks Company was dissolved.

In 1831, the Common Council again cast about them for a supply of water; and the frightful ravages of cholera in 1832 quickened their operations. The Croton river, distant 38½ miles, was thought of. An open aqueduct was first suggested; but finally a closed aqueduct of masonry was decided upon. The cost of the work, as estimated for this plan, and presented to the Water Commissioners, (including the cost of the city mains and conduits,) was 5,412,336 dollars.

The construction of the work was commenced in May 1837; and on the 22d June 1842, the aqueduct first received the water from the fountain reservoir on the Croton; on the 27th June, the water entered the receiving reservoir at the city of New York, and was admitted into the distributing reservoir on the 4th of July.

The available capacity of the fountain reservoir is said to be 600 millions of gallons. The medium flow of the Croton river, where this fountain reservoir is formed, exceeds 50 millions of gallons in 24 hours, and the minimum flow is said to be about 27 millions of gallons. The aqueduct is 7 feet 5 inches wide at the springing of the arch, which is a semi; and across the invert, the width betwixt the side walls is 6 feet 10 inches, from the invert to the soffit, 8 feet 5½ inches high. The American engineers estimate that it is capable of conveying 60 millions of gallons each 24 hours. The curves which are used to change the direction of the line of the aqueduct are not less than 500 feet radius. Some few have a radius of 1,000 feet and upwards, but the majority of them are of 500 feet radius. There are waste weirs for surplus water, as also six stop-chambers and waste-gates, out of which the whole body of water may be discharged, leaving the length of aqueduct below free for examination and repairs. On each mile there are chimney ventilators, rising 14 feet above the surface, and every third is fitted with a side entrance. At every quarter of a mile, openings 2 feet square are formed in the arch, which are in general covered over with a flag-stone; they may be used either for entrance or for extra ventilation at any time such may be required. The bottom of the water-way of the aqueduct, where it leaves the gate-chamber, is 11·40 feet below the surface of the fountain reservoir, and 154·77 feet above the level of mean tide at the city of New York. The aqueduct has several planes of descent from the gate-chamber at the Croton dam to the receiving reservoir on the island of New York, as shown by the following table, commencing at the south side of the gate-chamber at the Croton dam:—

Mr. Rawlinson.

	Length.			Gradient, in Feet.	Fall per Mile.	Extra Fall where Pipes are used.
	Feet.		Miles.	Feet.	Inches.	Feet.
1. Plane of Aqueduct	26,099·72	or	4·943	2·94	$7\frac{1}{8}$	..
2. Ditto ditto	148,121·25	,,	28·053	30·69	$13\frac{1}{4}$	..
Length of Pipes across Harl River	1,377·33	,,	0·261	2·29	..	2
3. Plane of Aqueduct	10,733·14	,,	2·033	2·25	$13\frac{1}{4}$	..
Length of Pipes across Manhat Valley	4,105·09	,,	0·777	3·86	..	3
4. Plane of Aqueduct	10,680·89	,,	2·023	1·60	$9\frac{1}{2}$	..
Total	201,117·42	or	38·090	43·63	..	5*

* The extra fall of 5 feet would have been avoided if the aqueduct had been continuous. It is to compensate for the friction in the syphon pipes.

With a depth of water 2 feet, the flow throughout the entire aqueduct is said to have been one mile and a-half per hour. The receiving reservoir is divided into two unequal areas; the northern division covers 18·13 acres; the southern division 12·75 acres, making in both nearly 31 acres. The greatest depth of water is 20 feet, and the capacity of both divisions, when full, is 150 millions imperial gallons. These reservoirs are open and exposed.

Such is a brief sketch of this celebrated work, which was estimated at $5\frac{1}{2}$ million dollars, but is said to have cost upwards of 12 million dollars, a sum equal to 71,000*l.* per mile, placing the whole cost in contrast with the length of the aqueduct. But if the cost of the reservoirs at both ends, and the distributing apparatus is deducted, the actual cost of the aqueduct is upwards of 40,000*l.* a mile, equal in cost to some of our most expensive and extravagantly constructed railways.

In examining the Croton aqueduct, there are several things to be considered, as example, and also as warning. It was a bold step in modern times, to cast about and look for the best supply the district would afford; and contrary to existing usage, fearlessly to undertake a work which may be fairly considered to parallel the great works of antiquity. That water may with advantage be brought from a distance is now pretty generally allowed and practised, and as the subject becomes better understood, works of this character will be extended, but modern means and appliances in the use of bricks, tiles and the metals, should prevent any repetition of such works as the Croton aqueduct. In the Croton work, nothing has been learned or forgotten from the time of the Romans, every feature of it would have been equally well constructed 2000 years ago. It would be difficult to devise a more expensive work: to cross valleys, or where the natural surface of the ground falls below the plane of grade. The aqueduct is supported upon a foundation wall of stone, forming a solid wall or pier, 17 feet thick, varying in height to suit the natural contour of the valley, and the plane of the aqueduct; placed upon such wall or pier, the true aqueduct or water-way is constructed with a brick-lining upon a concrete foundation; the side walls are backed up with rubble masonry. The whole structure thus formed is banked up with earth on each side, trimmed off to a side slope of one

Mr. Rawlinson.

to one, the surface of the embankment being paved with rubble. The sectional area of the water-way is in some instances about one-thirtieth that of the whole work, including pier and embankment. On portions of the line, as at Sing-Sing, the Mill River, Jewell's Brook, Hastings, at Jonkers, Clendinning Valley, and other places, masonry structures of the most expensive character have been constructed; but, nevertheless, in several instances it has been found necessary to line the water-way with iron; this is the case over the Clendinning Valley, and at Sing-Sing Kill. At the Harlem River and Manhattan Valley two cast-iron pipes, of 3 feet interior diameter, descend into, and crossing both valleys, delivering the water into the masonry aqueduct on the opposite side. The cost of the Croton Aqueduct may be contrasted with the following table:—

Cost of Canals in England.

Canals, including Land, have cost per mile as under:—

	Length, in Miles.	Total Cost.	Cost per Mile.
		£.	£.
The Rochdale Canal . .	21½	291,900	13,900
The Ellesmere Canal . .	57	400,000	7,017
The Kennet and Avon .	78	420,000	5,384
The Grand Junction . .	90	500,000	5,555
The Leeds and Liverpool .	129	800,000	6,201
The Clyde Canal . . .	35	200,000	5,714
Total . . .	410½	2,611,900	About 6,370
The Croton Aqueduct .	38¼	2,500,000	About 71,000

Note.—The Rochdale Canal traverses a most difficult country: bridges and locks are numerous. The Grand Junction Canal passes more than once the great ridge of hills that divide the waters of England. The Forth and Clyde Canal, in Scotland rises and falls 160 feet vertical, by means of 39 locks: it is 8 feet deep of water, and passes vessels 19 feet wide.

The average cost of these canals is, it will be seen, many times less than the cost of the Croton aqueduct. The canals have, however, for the most part an open channel of earth-work, but there are numerous bridges, culverts, embankments, tunnels, aqueducts, and locks, some of which works are of a heavy and expensive character.

The question of construction with respect to the New York aqueduct, was, it appears, discussed at the outset, and to quote from a description of the work, "The following modes were presented: a plain channel formed of earth, like the ordinary construction of a canal feeder; an open channel, protected against the action of the current by masonry; an arched culvert or conduit, composed essentially of masonry; or iron pipes. An open canal was objected to, on account of exposure to impurities from surface washings, and liability to stoppage from frost; an open channel of masonry had the same objections made to it; and a continuous line of iron pipes was rejected, because of the vertical undulations, which would offer so much resistance to the flow of water that the discharge would be diminished in a very great degree." This could hardly be considered, by any person fully acquainted with the principles of hydraulics, a valid reason at that time, and most certainly

Mr. Rawlinson.

is not so now; air valves on the upper bends would have been a security for the due action of the pipes; but the difficulty is not worth reasoning out. The New York engineer has been smitten with the works of Egypt and Rome to such an extent, that nothing less than a work equal or superior in massive grandeur would serve for modern use. Like many later works, in this country, railway works for instance, appearance and personal fame have been more considered than true economy. This was not the case with our most celebrated canal engineers, who studied practical utility in conjunction with strict economy, and they produced works equal to the requirements of the time and age, at a minimum cost.

The use of iron, wrought and cast, may be much more extensively employed in water-works than has hitherto been the practice; and, each placed where their capabilities may be best used, works of equal grandeur and magnificence to any of modern or even ancient times, may be constructed for a first cost many times less. Where it is not thought advisable to cross a valley or river by an inverted syphon-pipe, an elevated wrought-iron tube-aqueduct may be constructed, light, elegant, nay, even graceful in structure, and which shall be capable of carrying a volume of water equal to that brought by several of the Roman aqueducts combined. Telford set an example in his celebrated Pont-y-Cyssylte Aqueduct, which is 126 feet in height, 1,007 feet in length, and has a cast-iron water-way as sound and perfect now as the day it was made. For the purposes of a water-supply merely, this aqueduct might now be constructed at the same elevation, to carry the same volume of water (namely, about 20 millions of gallons daily), at one-fourth the cost; as two-thirds of the present piers might be dispensed with. In July 1846, I proposed a plan to the corporation of Liverpool, to bring in a supply of water from the river Dee, known by the name of the Bala Lake Water-works scheme, as the Dee rises in that lake. It was however proposed to take the water at a point of the river three miles above Llangollen, about 325 feet above low-water level at Liverpool. The whole length of the aqueduct would have been 64 miles, but for 40 miles the upper edge of the valley of the Dee would have been contoured, and in no district could land more favourable for a work of this class be found. The several intermediate valleys would have been crossed with inverted syphons, or by means of elevated aqueducts of wrought iron. The plans for which were submitted to Mr. Fairbairn, who reported as follows:—

"*To the Chairman of the Water-works Committee, Liverpool.*

"Sir, *Manchester, October* 1846.

"Mr. Rawlinson has submitted to my inspection drawings for sheet-iron aqueducts for conveying water across the Weaver, and other valleys from the river Dee to Liverpool.

"In forming an opinion upon this project, several considerations present themselves: 1st, security; 2nd, durability; 3rd, as to the comparative expense between this mode and inverted syphon-pipes; 4th, atmospheric effects, or the changes to which the iron aqueduct would be subjected during the extremes of temperature at different periods of the year; and lastly, the effects of high winds.

"With regard to the first, I would observe, that rectangular troughs,

Mr. Rawlinson.

or, rather, tubes, 6 feet deep and 2 feet wide, with close tops, can be made of sufficient strength to carry 33 tons of water on 100 feet span, and equal to 12 square feet of area: the weight of 100 feet of such a tube will be about 12½ tons.

"2nd. Durability. In this respect, care must be taken to prevent oxidation, and in order to do this effectually, it will be necessary to make the top of the tubes, as all the other parts, perfectly water-tight, and the tube being always full of water, it will be a great security against corrosive action in the interior. On the outside, the usual preservatives must be applied; with these precautions, the tubes might last for an almost indefinite period of time.

"3rd. The expense of the iron portion of the aqueduct will be about 20,800*l.* a-mile; that is, computing the tubes and erections at 32*l.** per ton, or about 400*l.* for 34 yards. In this estimate I have not included the cost of the masonry, which I have left in the hands of the engineer.

"4th. The effects of winter, or the change of temperature, will not be severely felt on a long and somewhat flexible tube. Internally, the temperature will not vary considerably, as it never can be above 60°, and never lower than 32°; and any expansion or contraction from that cause will not seriously affect the stability of the tube.

"Lastly. The effects of high winds will not in any way endanger the security of the structure; as, taking the lateral pressure at 50 lbs. upon the square foot, the whole lateral pressure will not exceed 13¼ tons.

"Now the weight of the tube, and the water it contains, will be 45½ tons; consequently, the vertical will be to the horizontal pressure as 3½ to 1 nearly, exclusive of the lateral strength of the tube.

"Altogether, and under all the circumstances, there is no difficulty in conveying the water in the way proposed, provided that necessary attention be paid to the erection of the piers and the construction of the tubes.

"I am, Sir,

"Your faithful obedient servant,

"W. Fairbairn."

The district drained by the Dee above the proposed junction of aqueduct is of vast extent; 289 square miles; and the volume of water poured down the river at the same point equals 365,000 millions of gallons annually, or an average of 1,000 million gallons each 24 hours. Geologically, the district is most favourable, as the rocks are principally clay-slate, and the water seldom exceeds one degree of hardness. The estimated cost to deliver 30 millions of gallons daily in Liverpool was a little under 600,000*l.*

The extent and character of the Roman aqueducts are tolerably well understood, though there is some dispute amongst antiquarians as to the number which actually entered Rome; according to some authorities (P. Victor), there were 20. Their united volume of water is said to have exceeded 500 millions of gallons of water daily (it is set down for nine of them at 376,834,379 gallons daily). "Some of these aqueducts brought water to Rome from more than a distance of 60 miles, through rocks and mountains and over valleys; supported on arches in some places above 100 feet high, one row being placed above another."

* Wrought iron structures could now be manufactured for a price much less than the one named here.

Mr. Rawlinson.

The care of the aqueducts under the emperors was entrusted to certain officers, called *Curatores aquarum*, with 720 men, paid out of the public funds, to keep them in repair. The declivity of an aqueduct was at least the fourth of an inch every 100 feet; where the water was conveyed under ground, openings to the air were formed every 240 feet.

The aqueduct of Spoletto, in Italy, is one of the finest structures ever erected by man; it is 420 feet high; the middle arch is 328 feet in clear height, supported on piers 10 feet 6 inches thick. Modern engineers may learn how to economize materials by a study of this structure. The main piers of Telford's otherwise beautiful bridge at Bangor, and the aqueduct at Pont-y-Cysylte, are clumsy and massive in comparison. The piers and land abutments at the Britannia Bridge, spanning the same straits, are most extravagantly costly and ponderous, contrasted with the aqueduct of Spoletto, or with the work they have to perform.

If modern science has taught us how to make a steam-engine, it has not yet fully inculcated the necessity there is that rigid economy should be studied in all engineering works. This, however, must be applied in an especial degree to all works connected with towns' improvements, namely, drainage and water supplies. If 20 houses can be perfectly drained and supplied with water for the cost hitherto charged upon one, and the work much better done, it is the duty of all concerned to see that so desirable a work is accomplished. In laying out new works, due regard must be had to efficiency, as to economy, and it must ever be considered that there may be many degrees of cost up to an extreme maximum estimate, but there is only one minimum; and it will require constant attention, labour, and care, to secure this. Incompetency is adequate to any of the first; knowledge and judgment, with care, are requisite to secure the latter.

Statement of the Estimated Cost of Pumping, for continuous discharge, the Sewage—including the soil-water and the greater proportion of the rainfall—of the Surrey and Kent District of the Metropolis.

Mr. Rammell.

The flat district of London on the Surrey and Kent side of the river is of very considerable extent, but its boundaries are not clearly defined. For the present purpose its area may be roughly estimated at 4,000 acres, the number of its houses at 80,000, and of its population at 500,000. It may be considered as forming about one-fourth part of the whole metropolis.

This district being placed in great part on the level, or but just above, or below, the level, of high-water; is for many hours every day, all drainage from it by natural means, is stopped by a natural obstacle, the rising and falling river. In order, therefore, to relieve it from accumulations of house sewage and rainfall, when the outfalls are thus closed, it would be necessary to raise by artificial means these liquids above the level of the tide.

On the present system of intermittent drainage they are ponded up at such times in huge sewers, where, in a state of repose, their power of holding heavier matter in suspension being lost, the grosser and more offensive particles contained in them are deposited, to the manifest deterioration of the healthful condition of the district.

Mr. Rammell.

Steam is the most economical power that could be employed to raise the refuse for continuous discharge; and it is beyond question as fully applicable to the purpose of town relief from sewage accumulations as to that of town supply with pure water.

By pumping to the requisite height the discharge may be effected at any point, however distant; the height, of course, increasing accordingly as the outfall is more removed. Thus for discharge into the river at the most convenient and least objectionable point of the shore line of the district, say at Deptford, the sewage would have to be raised a certain number of feet; for discharge at Woolwich, a few feet higher; at Erith, a few feet higher still.

It appears that the length of the tidal flow of the Thames is about seven miles, and that of its ebb about ten miles. Sewage matter, therefore, discharged at low water at Deptford would be carried up by the returning tide as far as Vauxhall Bridge; at Woolwich, to near the Thames Tunnel; at Erith, to near Woolwich.

In the first supposed case, the pollution of the river from this source would extend along the whole of its course through the more thickly-built part of London; in the second, the pollution would reach far into the densely peopled quarters; in the last, no particle of the sewage would ever be carried above the lowest suburb—Woolwich.

The expense of pumping will, of course, bear a proportion to the height to which the sewage is to be raised; but it will not increase in an equal ratio.

Besides the greater expenditure for pumping in order to effect the discharge at Woolwich or Erith, instead of Deptford; a sum would have to be allowed for the pipeage requisite to convey the sewage to those places respectively.

The Board having requested me to furnish an estimate of the expense of relieving the district in question by pumping, I propose now to calculate, upon certain assumed data, what it would amount to in each of the three supposed cases of discharge, viz., 1, at Deptford; 2, at Woolwich; 3, at Erith.

The following data are assumed:—

(*a.*) That the height to which the sewage would have to be raised for discharge at Deptford would be 20 feet.

(*b.*) That for discharge at any lower point of the river this height would increase in the proportion of 12 inches for every mile of distance. (This would give a rate of fall for the outfall pipe of 12 inches per mile in addition to the fall of the river.)

(*c.*) That the cost of the outfall pipe would be 10,000*l.* per mile.

(*d.*) That the quantity of house sewage to be raised would be in the proportion of 20 gallons daily to every inhabitant.

(*e.*) That of the total rainfall of the district 24 inches would have to be raised.

(*f.*) That engine power capable of effecting the continuous discharge of the entire daily quantity of sewage (exclusive of rainfall) in the space of six hours would have to be provided.

The three following tables show the estimated annual expense of pumping for discharge at the three places respectively:—

Mr. Rammell.

TABLE I.

ESTIMATE of the ANNUAL EXPENSE of PUMPING by Steam Power the SEWAGE of the SURREY and KENT District, 20 feet high, for discharge at DEPTFORD.

Capital.

	£.
Two Cornish engines (duplicates) of 175-horse power each, at 55*l.* per horse	19,250
Engine-house (say)	7,000
Land for ditto (say)	1,000
Total capital	£27,250

Annual Expenses.

				£.	s.	d.	£.	s.	d.
Interest on Capital, Depreciation, and Repairs.									
To interest on 27,250*l.*, at 5 per cent.				1,362	10	0			
To depreciation on 26,250*l.*, at 2½ per cent.				656	5	0			
To repairs on 26,250*l.*, at 2½ per cent.				656	5	0			
							2,675	0	0
Working Expenses.									
To 960 tons of small coal, at 12*s.*				576	0	0			
To oil, hemp, tallow, &c., at 5*s.* a-day				91	5	0			
To wages—Engineer, 5*s.* 6*d.* a-day	£100	7	6						
" Stoker, 4*s.* 6*d.* a-day	82	2	6						
" Labourer, 3*s.* a-day	54	15	0						
" Manager, 3*l.* a-week	156	0	0						
				393	5	0			
							1,060	10	0
Additional, for Pumping Rainfall (annual depth 2 feet).									
To 375 tons of small coal, at 12*s.*				225	0	0			
To extra labour over regular working hours				150	0	0			
							375	0	0
Total annual expense of pumping sewage for discharge at Deptford							£ 4,110	10	0

TABLE II.

ESTIMATE for PUMPING the same, 25 feet 6 inches high, for discharge at WOOLWICH.

Capital.

	£.
Two Cornish engines (duplicates) of 218-horse power each, at 53*l.* 15*s.* per horse	23,425
Engine-house (say)	7,500
Land for ditto (say)	1,000
Total capital	£31,925

Annual Expenses.

				£.	s.	d.	£.	s.	d.
Interest on Capital, Depreciation, and Repairs.									
To interest on 31,925*l.*, at 5 per cent.				1,596	5	0			
To depreciation on 30,925*l.*, at 2½ per cent.				773	2	6			
To repairs on 30,925*l.*, at 2½ per cent.				773	2	6			
							3,142	10	0
Working Expenses.									
To 1,165 tons of small coal, at 12*s.*				699	0	0			
To oil, tallow, hemp, &c., at 5*s.* 6*d.* a-day				100	7	6			
To wages—Engineer, 5*s.* 6*d.* a-day	£100	7	6						
" Stoker, 4*s.* 6*d.* a-day	82	2	6						
" Labourer, 3*s.* a-day	54	15	0						
" Manager, 3*l.* a-week	156	0	0						
				393	5	0			
							1,192	12	6
Carried forward							£4,335	2	6

Mr. [G]ammell.

	£.	s.	d.	£.	s.	d.
Brought forward				4,335	2	6
Additional, for Pumping Rainfall (annual depth 2 feet).						
To 478 tons of small coal, at 12*s*. . . .	286	16	0			
To extra labour over regular working hours . .	150	0	0			
				436	16	0
Total annual working expenses, exclusive of outfall pipe . .				4,771	18	6
Add interest at 5 per cent. upon capital (55,000*l.*) sunk in 5½ miles of outfall pipe				2,750	0	0
Total annual expense of pumping sewage, and discharging it at Woolwich				£7,521	18	6

TABLE III.

ESTIMATE for PUMPING the same, 31 feet high, for discharge at ERITH.

Capital.

	£.
Two Cornish engines (duplicates) of 260-horse power each, at 52*l.* 10*s.* per horse	27,300
Engine-house (say)	8,000
Land for ditto (say)	1,000
Total capital . . .	£36,300

Annual Expenses.

Interest on Capital, Depreciation, and Repairs.				£.	s.	d.	£.	s.	d.
To interest on 36,300*l.*, at 5 per cent. . . .				1,815	0	0			
To depreciation on 35,300*l.*, at 2½ per cent. . .				882	10	0			
To repairs on 35,300*l.*, at 2½ per cent. . . .				882	10	0			
							3,580	0	0
Working Expenses.									
To 1,370 tons of small coal, at 12*s*.				822	0	0			
To oil, tallow, hemp, &c., at 6*s*. a-day . . .				109	10	0			
To wages—Engineer, 5*s*. 6*d*. a-day. .	£100	7	6						
„ Stoker, 4*s*. 6*d*. a-day . .	82	2	6						
„ Labourer, 3*s*. a-day . .	54	15	0						
„ Manager, 3*l.* a-week . .	156	0	0						
				393	5	0			
							1,321	15	0
Additional, for Pumping Rainfall (annual depth 2 feet).									
To 580 tons of small coal, at 12*s*.				348	0	0			
To extra labour over regular working hours . .				150	0	0			
							498	0	0
Total annual expenses, exclusive of outfall pipe . . .							5,402	15	0
Add interest at 5 per cent., upon capital (110,000*l.*) sunk in 11 miles of outfall pipe							5,500	0	0
Total annual expense of pumping sewage, and discharging it at Erith							£10,902	15	0

NOTE.—In each of the three cases given, one of the engines would raise, at ordinary working, the total daily quantity (10,000,000 gallons) of sewage in six hours. Upon emergencies the full power of both engines would raise as fast as produced, and in addition to the house sewage, a rainfall equal to a depth of $\frac{2}{10}$ths inches (nearly) in six hours over the entire area; and exclusive of the house sewage, a rainfall equal to a depth of $\frac{3}{10}$ths inches (nearly) in six hours.

Mr. Rammell.

From the foregoing tables it follows that the expense of pumping and providing for the discharge of the sewage (including two feet depth of rainfall) of the district, would be met by an annual charge per house and per inhabitant as follows:—

If spread over the district, and discharged at Deptford, per house 1*s.* 0½*d.* (12·33*d.*), per inhabitant 2*d.* (1·97*d.*); discharged at Woolwich, per house 1*s.* 10¾*d.* (22·56*d.*), per inhabitant 3¾*d.* (3·61*d.*); discharged at Erith, per house 2*s.* 8¾*d.* (32·71*d.*), per inhabitant, 5¼*d.* (5·23*d.*)

If spread over the entire metropolis, and discharged at Deptford, per house 3¼*d.*, per inhabitant 0½*d.*; discharged at Woolwich, per house 5¾*d.* (5·67*d.*), per inhabitant, 1*d.* (0·90*d.*); discharged at Erith, per house 8¼*d.* (8·21*d.*), per inhabitant 1½*d.* (1·31*d.*)

T. Webster Rammell.

London, May 1850.

Mr. Samuel Hocking, Civil Engineer, examined.

Mr. Hocking.

1. Are you not particularly engaged in the supply of Cornish engines?—I am.

2. Have you not supplied these engines in various parts of the country?—I have.

3. In some evidence as to the working of a Cornish engine in the metropolis of an 80-inch cylinder, given in the year 1844, it was stated, that with coal at the price of 12*s.* the duty done by the engine at that period was the raising of 80,000 gallons of water 100 feet for 1*s.* What would such an engine do now?—Since that period I have, as an engineer and agent to the firm of Sandys, Vivian and Co, Hayle, Cornwall (where these engines are made), erected some engines of larger size, which, principally from their increased size, enable us to pump water at a still cheaper rate. Supposing one of these engines constantly at work night and day, and at a moderate speed, it would raise, on an average, 87,000 gallons of water 100 feet high for 1*s.*

4. That is to say 388 tons of water?—Yes, 388½ tons of water lifted 100 feet high for 1*s.*

5. What is the size of that cylinder?—90 inches in diameter.

6. What number of horse-power according to the usual reckoning?—About 230 horse-power.

7. Was that in London?—Yes.

8. And what price do you calculate the coals then to have been?—12*s.* per ton for Newcastle small coals.

9. Supposing the supply for the Metropolis to be taken at 50,000,000 gallons a-day, to be lifted 100 feet high, how much would the average cost of pumping that quantity be?—28*l.* 14*s.* 8*d.* with engines of the largest size.

10. What would the supply per house be during the year, taking it at 75 gallons per diem?—27,375 gallons, or in round numbers 28,000 gallons.

11. What would be the annual cost of pumping 75 gallons per house per diem?—About 3·8*d.* or under *fourpence.*

12. Do you happen to know whether 100 feet would be a fair lift for the Metropolis?—It would be sufficient for some districts. But

Mr. Hocking.

the height to which the water must be pumped will depend on the elevation of the district and its distance from the engine-station. At one of the Water Works I know it is pumped to more than double that height.

13. Of course the smaller sized engines will not work to the same advantage as the larger ones?—The amount of labour is greater in proportion to the power employed, and the consumption of coals is also in an increased ratio.

14. Will you put in a scale of the actual survey of engines of the different sizes you have made?—The following table was put in by the witness:—

Cost of Pumping Water for the Supply of Towns by Cornish Engines of various sizes, using Newcastle small Coals at 12*s.* per Ton.

Size of Engine in Horses Power.	Quantity of Water raised to 100 feet high for One Shiling.	Annual cost per House, with a supply of 75 Gallons per Day.
H.P.	Gallons.	Pence.
230	87,997	3·73
180	80,436	4·08
135	74,862	4·38
100	67,848	4·84
65	61,549	5·33
40	54,905	5·98
25	43,214	7·60

N.B.—This Estimate does not include interest on outlay or the Repairs.

15. What is the size of the smallest?—A 30-inch cylinder about 25 horse-power.

16. How much more expensively would such an engine work in proportion than that of the 230 horse-power. Will you show it by a proportionate table of the whole?—About double the expense as shown in the table above. By an engine of 25 horse-power, 43,000 gallons only can be pumped 100 feet high for 1*s.*, whereas by the 230 horse-power engine, 87,000 gallons can be raised to that elevation at the same cost.

17. Then a single engine of about 25 horse-power for a single house instead of pumping the required quantity for 4*d.* would only do it for about double that sum?—It would be somewhat under 7¾*d* if done by the smallest engine.

18. That is the working expense, the interest of capital being omitted?—Yes.

19. Then this would be the additional working expense of delivering water at the base and delivering it 100 feet high?—Yes.

20. Supposing you had to pump the water to distribute it at the basement of the house, the cost of afterwards raising it 100 feet high would be what you have stated?—Yes.

21. What will any given quantity of coal converted into steam do in pumping by these engines?—A ton of coals will lift 1,600,000 (one million six hundred thousand) gallons 100 feet high.

22. Or, supposing a room filled with water 750 feet square, and

4 feet deep, what quantity of coal would it require to lift that water 100 feet high?—8 tons, 15 cwt., 3 qrs. If only 50 feet square it would be lifted with 87½ lbs. of coals. Mr. Hocking.

23. Is it not your practice in Cornwall to make it the stoker's or engine-man's interest to work the engines with the least quantity of fuel?—Yes. The coals are weighed out to each man and carefully registered against him; and if one does not make it do as much work as another, it is easily discovered.

24. And each man is promoted according to the work he does?—Yes.

25. Then you are enabled to register the power according to the work done?—Yes; it is registered and marked down according to the number of strokes made by the engine.

26. What is the quantity of coal consumed in these engines compared with others?—About one-third.

27. Is there any peculiarity in the kind of coal that it is necessary to use for these Cornish engines?—No.

28. Then in fact when we see a Cornish engine giving out little or no smoke, it is because the consumption of coal is the more complete? —Yes. In Cornwall, however, the coal used is from Swansea, and it gives off less smoke than the Newcastle coal.

29. How is it with Newcastle coal when used in Cornish engines? —The quantity of coal consumed is not more than one-third of the quantity used in other engines; and by having much more boiler surface in proportion to the quantity of coal consumed, and a very weak current of draft through the flues, the smoke remains longer over the fire and more of it is consumed.

30. Then the use of Cornish engine involves a saving of two-thirds of the coal, and a consequent dimunition of two-thirds of the smoke?—Yes; even to a greater extent than that, probaby one-sixth part of the smoke given off by ordinary engines would be nearer the truth.

31. With 100 horse-power Cornish engine, what would be the saving of coals per diem, calculating the coal to be respectively at 5*s*., 8*s*., 10*s*., 12*s*., and the London price 1*l*. per ton?—

	£.	*s*.	*d*.
Coal at 5*s*. per ton, the saving per day would be	1	16	0
,, 8*s*. ,, ,, ,,	2	17	0
,, 10*s*. ,, ,, ,,	3	12	0
,, 12*s*. ,, ,, ,,	4	6	0
,, 20*s*. ,, ,, ,,	6	12	0

Annual saving at the present price of small coals in London (12*s*. per ton) and working six days per week, would be on 100 horse-power engine no less a sum than 1,345*l*. And for one of the largest engines the saving would be, per day, 7*l*. 11*s*., or per annum, 2,363*l*., which would represent a capital (at 5 per cent. interest) of 47,260*l*.

32. Also make the same comparison with a 25 horse-power Cornish engine?—

	£.	*s*.	*d*.
Coal at 5*s*. per ton, the saving per day would be	0	11	6
,, 8*s*. ,, ,, ,,	0	18	6
,, 10*s*. ,, ,, ,,	1	3	0
,, 12*s*. ,, ,, ,,	1	8	0
,, 20*s*. ,, ,, ,,	2	2	0

Mr. Hocking.

33. Also the actual annual expense of working different sized engines, say a 200 horse-power, a 100, a 50, a 25, and a 10 horse-power engine?—I keep no account of "the actual annual expense of working" the engines which I supply, as they are worked at the expense of the Water Companies, and are entirely under the control and management of their engineers.

34. What are the prices of the different sized engines, and what would be the annual working expense of them, the original outlay, and a fair allowance for annual depreciation?—The cost of these engines will depend on circumstances, which are found to differ in almost every case. Engines of the largest size will cost, when set to work complete, about 50*l.* per horse-power, the smaller one somewhat more. The "allowance for annual depreciation" of the Cornish engines employed at Water Works will, in no case, exceed the amount allowed for that of the ordinary engines working under the most favourable circumstances. I know of no accident happening to them since their first introduction to Water Works, about 12 years ago, whilst their repairs have been of a very trifling and inexpensive kind.

Joseph Quick, *Esq.*, examined.

Mr. Quick.

1. Are you not engineer to the Southwark and Vauxhall Company and consulting engineer to the Grand Junction Company?—Yes, I am.

2. What quantity of water is pumped per diem by the Grand Junction Company?—Between three and four millions of gallons, or an average daily supply throughout the year of 3,541,716 gallons.

3. To how many houses or buildings?—14,058.

4. What do you estimate the average quantity delivered per diem to each house in this district?—The average daily supply for domestic use in the past year has been 223 gallons per house, or 25 gallons per head; or, for all purposes, including road-watering, railways, &c., 252 gallons per house, or 28 gallons per head.

5. By a former Return it was stated that the delivery in the district of the Grand Junction Company was upwards of 300 gallons; has the quantity been decreased?—I think there must have been some inaccuracy in that return, partly perhaps arising from the supply being then only given three days in the week, and partly from a less perfect arrangement of mains and stop-cocks: there has also been since a more exact account taken of the number of separate tenements.

6. What is the quantity pumped per diem by the Southwark and Vauxhall Company?—Between six and seven millions of gallons, or a daily average throughout the year of 6,011,225 gallons.

7. To how many separate houses and buildings?—35,511.

8. What do you estimate as the average quantity delivered to each house or building per diem?—143 gallons daily throughout the year for domestic use, being 22 gallons per head; or 169 gallons, which includes the supplies to railways, manufactories, road-watering, &c., being 26 gallons per head.

9. Are not the houses on the south side, or in the Southwark and Vauxhall district, (on the average) of a much lower class in rental and condition than those of the Grand Junction? — Certainly, very greatly so; but it is difficult to draw a comparison between the districts.

10. In what way may the Commissioners least inconveniently to the Companies verify the fact as to the quantity of water daily distributed by them to their tenantry in each district?— Mr. Quick.

"*Waterworks, Sumner-street,*
"*December* 20, 1849.

"Sir,

"I beg to lay before you the following instructions for the purpose of ascertaining and verifying the quantity of water pumped by the London Water Companies and supplied to their tenantry in the past year.

"1st. To take an account from the engine-book of the number of strokes of each engine (each engine being named or numbered), and to measure the capacity of the pumps, to ascertain the quantity of water delivered.

"2ndly. To appoint some engineer to visit each of the Waterworks establishments, to take the counters of the engine for a given time, and also to gauge the pumps for the delivery.

"I am, Sir,
"Your obedient servant,
(Signed) "J. Quick."

11. Do you know the average size of butts and cisterns to the lower class of dwellings?—They are very various; ranging from a small pork-tierce of three or four gallons, to an 18, 54, or 63 gallon cask, but seldom approaching to the latter. Cisterns are very rare in small houses, and when put up do not contain more than 40 to 50 gallons.

12. Are not butts of the size of 100 gallons very rare in the Southwark district?—Yes; there are very few of the smaller class of six or eight roomed houses that have above a 63-gallon cask; but houses of a better description will have receptacles that contain between 100 and 200 gallons.

13. Have you ever had an opportunity of gauging the contents of butts, and the quantities of water consumed?—I have lately made some experiments, and find that the butts of four, six, and eight roomed houses, containing 40, 50, and 63 gallons respectively, are, on the average, about half emptied in a day; so that when the water is turned on only half a butt would be required by 19 out of 20 houses; but it generally happens that the twentieth is a baker or butcher, or perhaps a public-house, with a butt or cistern in an elevated position, for the convenience of his business or the saving of room; and to satisfy the wants of this one tenant the water has to be kept on three or four times longer than would be sufficient for the ordinary supply; and the waste going on the whole time from the adjoining houses, brings up the average daily supply to 143 gallons for each house.

14. Then you think that the butts served them well, as far as your observation went, when the supply was given on alternate days?—Yes; but not so well as now, with the exception of the very poorest districts, in which, when the Company supplied on alternate days, butts were provided; but since the water has been turned on at a certain hour every day in the week, many take their chance of filling any vessel they may possess during the time it is on. The daily supply has been afforded by the Company for nearly two years.

15. Has your number of customers increased in a greater ratio

Mr. Quick. since the daily supply has been given?—Not more than previously, as the same amount of water in the aggregate was allowed to each house as at the present time; the only difference being that it is now turned on for one hour daily, in place of two hours every other day.

16. Have you seen a set of gaugings made on a block of 1300 houses, on the north side of the Thames, which were supplied with water, and where it was proved that the quantity of water daily consumed from the cisterns was 51 gallons per house?—I have; and I believe that quantity to be a fair average of the positive consumption for the middling classes of houses, and it quite accords with my own observation.

17. In that particular case, and in others also, the general conclusion has been stated, that the quantity of water wasted is absolutely three times greater than the water consumed?—I believe that to be the case; generally I know it to be so in the Southwark and Vauxhall district.

18. Then the only difference is, that on the north side the water is silently conducted through a waste-pipe from the cistern to a drain, and on the south side is allowed to run over the sides of a butt and saturate the earth?—Yes, and in many cases it causes the most serious inconvenience to persons situated on lower levels than their neighbours, by flooding them every time the water is turned on, and it is one of the arrangements that would require the most serious consideration in any new system of supply.

19. Mr. Roe stated that, on an average, the supply did not exceed 76 gallons for the highest class of houses, even where there are three water-closets and baths?—I believe that if you were to take the average of a number of houses in any district, 76 gallons would be found sufficient, but I am disposed to think houses having three water-closets and baths would in most cases be found to consume a much larger quantity.

20. Have you observed the house-drains in action with this intermittent supply?—I have frequently.

21. What was their state, notwithstanding this waste of water?—In many instances they were filled up with black matter; they had gone on for years, until a final stoppage took place.

22. Then from the construction of house drainage, according to your experience as an engineer, you corroborate the opinion that the deposit was not removed by the flow of water on the days of supply, but went on increasing until it was removed by hand-labour?—Yes.

23. And you agree that the common estimate of water-supply is greatly in excess?—Greatly.

24. Does your own experience corroborate the statements of the fact that in butts and cisterns the water in a close atmosphere becomes tainted?—All waters are liable to become tainted in an impure atmosphere, but where the butts or cisterns are properly situated and attended to, the water will keep pure for a great length of time.

25. Have you examined the system of constant supply as it is carried out in Preston?—I have.

26. Are the houses there, occupied by the labouring classes, on the whole of a better description than those occupied by the labouring classes in Lambeth aud a large portion of Southwark?—Yes, both as to size and convenience; they are mostly provided with washhouses and sinks, and all the conveniences necessary for the comfort of a family.

Mr. Quick.

27. The manager of the works in Preston stated in evidence that their average supply to 6000 tenements was about 50 gallons per house per diem?—I have no doubt, from the great care that is taken to prevent waste, that the quantity named is correct.

28. There is a large proportion of manufactories included in that average of supply?—I wsa informed that was the average daily quantity used for all purposes of consumption, and that it was found to be sufficient for a population having larger demands for water than an average one.

29. Did you examine any other works than those at Preston where the system of constant supply had been in action?—Yes, at Nottingham, where I questioned several of the housekeepers (both in the higher and lower portions of the town), to see if they were inconvenienced by the water being turned off at any time; I was informed that, before the water is turned off, a notice is sent from the Water Company to each tenant, with an intimation that the supply will be stopped from a certain time to a certain time. They know accordingly what quantity of water to draw off before the main is shut; but this happens so seldom, that they think nothing of it.

30. What is the smallest size main-pipe you know to have been used for the service of mains?—The smallest lead pipe for the service of a number of houses was a 1-inch pipe; it was the entire side of a long street of some 35 or 40 houses.

31. Under what head of pressure?—I only know that in the middle of the day we went to the last house. We examined and asked the person whether the water was on, and we were told it was never off. That was a house at the highest end of the street, and the flow was very free from a half-inch pipe.

32. Has there been an instance of constant supply put on in London for tenements occupied by the poorer classes?—Yes, on a small scale, in Rose-court, Dockhead; and a small part of Jacob's Island, Bermondsey. The agent to Rose-court applied to the Company to ascertain the best means of improving the supply to his tenements, and at the same time get rid of the nuisance of a common tap, which was running for two or three hours every day, and causing perpetual quarrels between his tenants and the people from Jacob's Island, who had not any supply from the Company. It was recommended to take away the common tap and erect a tank in some central situation, and lay an inch lead pipe with a half-inch branch to each house. This has been done, and the result has been a marked improvement in the people; as they now pay their rents regularly, being fearful that they would not find the same accommodation if they were to go to other houses; and the agent informed me that he was so well satisfied with the arrangements, that he would have the whole of the houses under his care laid on in the same way. The Company have also been gainers, as they save at least 200 or 300 gallons of water daily. The other supply is to 10 houses on a part of Jacob's Island, from a tank and an inch lead pipe with a half-inch branch leading into each house; the same result as regards the tenants has taken place in this case.

33. And you advise then, as the preventive for this disorder, that a constant supply should be laid on from one general reservoir or tank to small houses?—I believe that would be the most efficient way of affording a constant supply to large blocks of small houses, and it

Mr. Quick. could be arranged very economically by persons availing themselves of the use of the Company's pipes beyond the branch leading into the tank as a feeder to the house services. It would also be a great protection to the high-service of the district, as all the water must ascend to the height of the tank before it could be drawn off; and if the Company's pipes could not be used to conduct the water, a small service of 1-inch or more in diameter, leading from the tank with ½-inch branches to the houses, could be laid in the most convenient situation, and would be the least expensive mode of giving a supply to houses that are not at present laid on.

34. Will you state the result of the experiment as to the comfort of the people?—The difference is very great; the agent to the estate informs me that quarrelling has scarcely been known among his tenants since the alteration, that the tenants never refuse to pay him the rent, and that he could obtain 3*d*. or 6*d*. per week more for each house, if any of them became empty; and if he had 100 houses in the neighbourhood, with water laid on in the same way, he could find tenants for them at increased rents.

35. And the great waste must have saturated the ground and caused much dampness in the neighbourhood?—Yes, and the paving-stones were often washed up and the inside of the houses made very damp. The tank holds about 210 gallons, and provides an ample supply for 10 small houses, at about 20 gallons per diem for each house. The tank is filled every day.

36. With an average population then that is enough?—On an average it is as much as is consumed in houses of that class—four-roomed houses.

37. From this case you may assume that the benefit might be extended to a larger class of houses?—Yes, to all, not only with advantage to the people themselves, but the Company also.

38. What do you apprehend would be the difficulties of changing the system from an intermittent to a constant supply?—The greatest difficulty would arise from the very defective state of the house service-pipes in poor districts, and the waste-pipes of cisterns in the better class of houses; also in making provision for supplying large manufacturers, road-watering, &c., at low levels at the same time that supplies would be required from services in the highest situations in the district. The first question would involve a remodelling of the lead service-pipes; and the second, a total change in the arrangements of the house cisterns, as I believe waste-pipes from cisterns would be fatal to any system of constant supply. The third could be arranged either by laying down a separate main, or by each manufacturer providing himself with a tank of sufficient capacity for his daily requirements, which could be filled at any convenient hour of the night; it would also be necessary to give the entire control over the lead service-pipes and everything connected with them to the Company, so that deficiency of supply, or waste of water, might at once be remedied by their servants and under the inspection of their officers.

39. It has been stated that smaller branch-pipes are used for the constant supply than for the intermittent one?—That I found to be the case at Preston and Nottingham, and I believe it would apply generally to supplies taken at nearly the same level.

40. How is it at Oldham, where water is delivered under 400 feet

pressure?—There, no doubt, the height would be great enough above the town to overcome the difficulties of the differences of height in it. Mr. Quick.

41. What is the proportion of breakages and other accidents to iron pipes?—Accidents seldom happen to the leading mains if properly laid, they are generally confined to the side services and small branch mains, and I believe they are caused by the vibration of heavy loads passing over them, and the sinking of the earth from defective sewers, &c. We find that one labourer is sufficient to make good all reparations required in each turncock's district.

42. What is the size of the districts?—Each turncock has to supply about 3000 houses and large consumers daily in the Southwark and Vauxhall district, and nearly 2000 houses in the Grand Junction district; the size depends upon whether it is in a crowded or suburban district. The Southwark and Vauxhall Company employ twelve turncocks, and the Grand Junction eight, each turncock being allowed one labourer. They are paid, according to their class, 18*s*., 20*s*., and 21*s*. per week. There is a great expense in paving, plumbing, &c.

43. With respect to the laying of pipes, are you able to distinguish any difference between the wear and tear of those laid in the front streets as compared with the wear and tear of those laid in the back streets?—A great deal will depend in all cases upon the way in which the pipes are laid; when experienced persons have been employed to carry out work of this description, little or no repairs are required, but if the pipes have been badly laid, they are a constant source of trouble and expense—they would be less liable to accident by being laid at the backs of houses.

44. Do you not think that the liability to accident would be greatly diminished by laying the pipes close to the houses?—Very much. We generally lay them, where practicable, within 2 or 3 feet of the kerbstone.

45. Has it not been found that house-drainage conducted at the backs of houses is more efficient and can be kept in repair at two-thirds less cost than when carried to the fronts?—Yes, it is better where convenient; but it is seldom that people will agree to have pipes or drains laid across their yards or gardens for the accommodation of their neighbours; and generally the property in any line of street is in the hands of so many different parties, that it has been found almost impossible to carry out any works of this description on a large scale.

46. But if it were a public regulation?—Then people would be glad to permit it.

47. Are there not frequent floodings from the breakage of the lead pipes passing under the houses?—Yes, and they would be avoided by having a small iron pipe laid along the backs of the houses.

48. Do you think that the expense of laying on a supply of water would be one-third less at the back of the houses than at the front?—Yes, particularly for small property; and there would be also the advantage of not having to cross areas; and, therefore, there would be less exposure to frost.

49. What depth is best for the sake of temperature?—The usual depth is 2 feet 6 inches below the surface; that is found to be sufficient to prevent the frost getting to the pipes.

50. You may be aware that it is stated to be important to get the

Mr. Quick. water delivered at a low temperature, particularly for water-closets, to check decomposition?—I believe it is so stated, and I should think that water travelling through a pipe at a mean depth of 3 feet (the average depth of the Water Companies' mains) have all the advantage of being kept cool in summer, and are sufficiently protected from frost in the winter.

51. You say upon your plan you would have a cistern for the constant supply of water; are you not aware of the objection to water standing in cisterns at all?—Yes, but the cisterns I have proposed for a system of constant supply are not to be used as reservoirs; they are merely intended to assist the general high service by preventing waste at low levels, and to act as safety valves to the lead pipes, which are generally manufactured of material too light to bear the pressure of the column of water which is acting on the leading and trunk mains, and they are, also, generally old and in a defective state.

52. In how many instances do you find the ball-cocks in action where cisterns and butts are in use?—The difficulty is in finding any, as in most cases the ball is taken off the cock and the water allowed to run down the waste-pipe into the drain or cesspool, saturating the ground and increasing the dampness of the neighbourhood.

53. Under the system you propose, of a small cistern with a hood, there would be comparatively small exposure to the atmosphere?—Very little or none. The action of the atmosphere would be very small indeed.

54. You have observed, doubtlessly, water in rooms to be in a very different state from that in which it has been delivered from the Water Company's service?—Very different, where exposed for any length of time to the tainted atmosphere of a crowded room, or stored in a foul vessel. But I have not observed any change take place in Thames water that has been properly filtered, and kept in butts or cisterns well situated. The water taken direct from the main is very pure, and quite fit for domestic use.

55. The water has been aërated in a comparatively pure district, compared with most of the districts to which it is supplied?—Certainly; and it is only in very unfavourable situations that the water is found to have the slightest tendency to become fetid.

56. Vitruvius says, that earthen pipes were used by the Romans at such heights as 100 feet; and instances have been adduced of Roman 3-inch pipes remaining even now at three or four times that height?—I have no doubt of it.

57. Have you laid any earthen pipes with a view of testing their strength?—Yes; and although the trials were not successful, I believe that with more perfect arrangements, and some alterations of the pipes, they might be used in suburban districts, and in small towns where there is not much heavy traffic to cause vibration.

58. We now see remains of considerable cities, and a system of earthen pipes laid down, apparently on a system of constant supply?—Yes; with cisterns or fountains.

59. Why should not the Roman system be carried out, with an increased purity of the water?—There is only one objection: if the water was very pure it would act on the present lead pipes; if it were 7, 8, or 10 degrees of hardness, it would not act on the lead.

Mr. Quick.

60. Have you seen Mr. Austin's plan for the removal of sewer water; do you think there would be any probable obstructions in the pumping of such water?—None whatever, if precautions were taken to prevent quantities of straw or other floating matter accumulating in the pump-wells. I believe Mr. Austin provides against such obstructions by catch-gratings and other suitable arrangements.

61. Have you had brought under your notice experiments of street-washing by jets?—I have. I was present at experiments at Battersea regarding the force of jets of different forms for the distribution of water.

62. Then you have seen the report of Mr. Lovick on the washing of surfaces?—I have.

63. In respect to the rapidity of application, and the quantity of water used, do you concur in the result of the experiments stated?—Quite so. With a powerful jet, no doubt more work could be got over than with a jet at a low pressure.

64. With what power of jet would you work then?—All will depend on the size of the main, and the number of jets it would be necessary to have open at one time to get through the work; the fewer the jets and the shorter the hose the greater will be the power. There would be great difficulty in attaching any system of standpipes for street-watering to the present fire-plugs, and I believe it would be found necessary either to lay down a separate line of small pipes with proper stop-cocks and outlets, or transverse services from the present mains to the kerbstone with the same appliances.

65. Is a gallon per square yard a large average for washing?—After the first and second application I should think it was.

66. Have you seen the form of plug of the kind called Ghrime's plug?—I have not seen any plug that I think well adapted for this purpose; it ought to be something very strong and simple—easily repaired, and combining in itself the means of shutting off the water from the main, and attaching the hose-pipe with the common joining-screw.

67. Do you think that, with proper arrangements, these cleansings might be performed with rapidity by means of the jet, and with greater comfort than by any process of sweeping?—No doubt, if it could be done at convenient hours, and so as not to interfere with the house-service. In the constant supply, too many plugs opened in a low level would draw all the water from the upper levels and disturb the supply of an entire district, unless separate mains were laid for the purpose.

68. Does it consist with your observation that Mr. Lovick's estimate is a full one?—I think it is beyond an ordinary estimate.

69. Are you aware that at Philadelphia, where there is a constant supply, this system is in operation at a time when the servants are cleaning the door-ways, and yet is so managed that there is never any complaint of deficiency of supply?—I know that when we have a large fire we are obliged to shut off most of our services to compensate for the water flowing from the plugs at low levels, which generally interferes with the supply to the entire district.

70. Have you any means of regulating the supply to the demand?—The means of which we make use is to work the engines fast or slow so as to keep up the pressure in the mains to the height of the standpipes, and that is done by the engine-workers observing a mercurial gauge

Mr. Quick. attached to the trunk mains and fixed in the engine-house. The engine also itself strikes a bell, which instructs the men either to increase or diminish the speed, and this arrangement has been found to answer perfectly.

71. May we not expect great advantage from a constant supply of water, and the ready means of the application of it on emergencies?—No doubt of it, for half the large fires are occasioned by the immediate want of water to check them in their origin, and that causes them to become large fires.

72. There would be peculiar advantages in large candle and other factories?—Yes, and many railway stations have availed themselves of the Company's mains, by having a branch with joining screws taken into their premises, so that a hose-pipe can be attached and the water turned on immediately upon an alarm being given.

73. Would it not be one recommendation of street-washing that the hose would be at once prepared ready for immediate use, instead of having to send some distance for engines?—It would be important in all districts.

74. How many houses has each turncock?—About 3000; and each one has a labourer, who is employed in assisting and seeing to where pipes have burst or repairs are required.

75. Mr. Hawkesley states, that one man with a boy was able to keep the Nottingham water-works district in order?—That may be the case in a small district; we find that it takes on the average one turncock and one labourer to every 3000 tenants supplied. This number of attendants would no doubt be diminished under a system of constant supply, but I cannot say to what extent.

76. You have observed the sewer water; what was the state of the Thames water at the time they were pulling down London Bridge?—In the neighbourhood of their operations it was much more charged with heavy matter than ordinary sewer water from the disturbance of the chalk and rubbish which had been placed as a protection to the piers of the old bridge.

77. Do you feel any doubt as to being able to pump sewer water—Not if large or solid bodies are kept out of it.

78. What is the total quantity distributed in the metropolis daily?—About 50 million gallons daily; the minimum quantity may be 47 millions, and the maximum 60 on very dry days.

79. Is that a filtered supply?—There are but 3 of the London companies that give a filtered supply, viz., the Grand Junction, the Chelsea, and Southwark and Vauxhall.

80. At the rate you effect filtration it would not be worth while to convey filtered water for one kind of service and unfiltered for another?—No; another service of pipes would be a greater expense than the whole cost of filtering the entire quantity.

81. Of course, filtered water is less obnoxious to accidental causes?—I believe filtration to be indispensable to all waters; as a general rule, the more water is covered and kept from the air the better it is.

82. From your knowledge of other districts and the habits of the population, have you any reason to doubt that the same wants felt in your district are experienced in others?—I have not.

83. Have you anything to say with regard to the increasing pollution

of well-water?—Several wells in the metropolis have lately become so polluted as to have been disused; and in every situation where the population has been rapidly increasing, the well-water becomes thus affected. Mr. Quick.

84. If a system were adopted to prevent waste, do you see any grounds for supposing that the present water-supply would be in excess, after providing for street-cleansing, washing the fronts of houses, the use of baths, and other sanitary purposes?—I have no doubt that if proper means were adopted to prevent waste, a quantity of water, far more than sufficient, is at present supplied by the companies, for every purpose.

85. Has it been the practice of your Company to allow parties to join on to the trunk-main?—The trunk-mains are seldom tapped, except for the fire-service, but much use is made of the branch mains.

86. Even so far back as 20 years, were not persons allowed to have water direct from the main?—Yes, by making special arrangements as to price and quantity.

87. What additional quantities of water could the Grand Junction Company and the Vauxhall Water-works Company supply, with their present Works?—The present daily supply afforded by the Grand Junction Water Company during the past year has averaged, for seven days in the week, 3,544,716 gallons, and the engines which pump this quantity, by being worked their full time, would deliver 6,321,600 gallons. The Company have also, in addition, two powerful engines, capable of raising 6,566,400 gallons to an elevation of 150 feet, or 68 feet below the top of the stand-pipe. By a reduction of the pumps, they could be rendered capable of lifting 3,988,000 gallons to the height of the stand-pipe. The gross quantity the Company could then deliver at an elevation of 218 feet (minus the friction to be overcome in the flow of the water to London) would be 10,309,600 gallons, or three times the present supply. The present loss of head by friction would appear to be from 6 to 10 feet.

The Company have also two lifting-engines capable of raising 13,478,200 gallons of water from the Thames daily to their depositing reservoirs and filtering-beds, which reservoirs and beds are capable of nearly twice the work they at present perform. They have also land sufficient to increase their filtering reservoirs to any necessary extent.

The height of the stand-pipe being 218 feet, and the trunk main 30 inches in internal diameter, the above quantity of water could be pumped into the Company's district, in which the mains and services would be sufficient for its distribution.

The quantity of water supplied daily by the Southwark and Vauxhall Water Company during the past year, (seven days in the week,) has averaged 6,011,225 gallons. The same engines which pump this quantity, if worked to their full power and time, would deliver 8,000,000 gallons. The Company have also a spare engine, which, by reduction of the pump, could be made to lift 1,200,000 gallons daily, making a gross quantity of 9,200,000, or 50 per cent. above the present supply. The Company have provided room in their engine-house for an additional engine, capable of lifting 9,400,000 gallons to the top of the stand-pipes, and they would then have the power of giving a supply

Mr. Quick. three times greater than their present. The Company possess reservoirs of deposit and filtration quite equal to the gross quantity that could be pumped, and they have also spare land for additional filter-beds. They have, by a 4-feet culvert-pipe and a lifting-engine, the means of taking the whole of the water they at present use from the falling tide, after the London drainage has passed down the river, and any further quantity that might be required by the addition of another engine of the same description, the culvert being amply sufficient.

The height of the stand-pipes being 180 feet above Trinity high-water mark, their trunk mains of 20 and 27 inches diameter are quite equal to convey a double quantity of water, if required.

It will be understood that the quantities given above are the whole duty the engines would be capable of performing in actual working; allowance must be made for the time required for cleaning and occasional repairs, and also for the reserve necessary against the contingency of accident.

88. What proximately might be the expense if the supplies for the Grand Junction district, or the Southwark and Vauxhall district, were taken, say from near Thames Ditton ?—With a view to afford a reply to this question, I have carefully examined the banks of the river between Thames Ditton and Kew Bridge, for the purpose of selecting a site for a pumping establishment that should be altogether beyond the influence of the London drainage, and where the water would be of the same quality as that passing at Thames Ditton.

The most suitable place for forming a work of this description I believe would be the Ait, or small island, opposite Twickenham, being situated within a mile and a quarter of Teddington Lock, and nearly five miles above Kew Bridge.

The accompanying plan will best show the position of the engine-house on the island, and the mains (coloured red) leading to the Grand Junction Works at Kew Bridge, and the Southwark and Vauxhall Works at Battersea Fields. Also the additional mains (coloured blue) that would be required to supply the West Middlesex and Chelsea districts from the Kew Works and Camden-hill reservoirs, and the Lambeth Company's district from the Battersea Works and the Brixton-hill reservoirs.

To effect these objects it would be necessary to enlarge the Kew Bridge Works, and make some additions to the Battersea Works.

The following estimates, numbered 1, 2, and 3, embrace the whole sums that would be required to form the pumping establishment at Twickenham: also to lay the mains to supply the two works of distribution at Kew Bridge and Battersea; the enlarging of the Kew Bridge Works and additions to the Battersea Works; and the laying of the mains for connecting the West Middlesex and Chelsea districts to the Kew Bridge Works, and the Lambeth district to the Battersea Works.

Estimate No. 1.—*Pumping Establishment at Twickenham.*

	£
Engines, &c.; engine-house, ground, &c.; culverts, &c., under the bed of the river to connect mains	50,000

Mr. Quick.

	£.
Brought forward . .	50,000
Estimate No. 2.—*Enlarging of the Kew Works.*	
(These estimates are made in reference to the present quantity supplied.) Additional engines, engine and boiler houses, land, filter-beds, and reservoirs, sundry connections, &c. . .	95,000
Additions to the Battersea Works.	
Additional engine, filter-bed, &c. . . .	25,000
Estimate No. 3.—*Mains from Twickenham to the Works of Distribution at Kew and Battersea.*	
Twickenham to the Kew Works, 6600 yards of 36-inch main; ditto to Battersea Works, 17,600 yards 30-inch; Kew Works to the junction with the West Middlesex main, 4850 yards of 30-inch; from Camden Hill to the junction with the 24-inch main passing through Hyde-park, from the Uxbridge to the Knightsbridge roads, and to the Chelsea Company's mains, 3500 yards 30-inch main . . .	121,550
From the Battersea Works to the Brixton-hill reservoirs, and connected to the Lambeth Company's mains, 4400 yards 24-inch main.	
	291,550
By land and old works . . .	100,000
	£191,550

89. In the distribution of water do you find often the practical results correspond with the doctrines in hydraulics deduced from mathematical formulæ, or from experiments on a small scale?—As far as my experience has gone, I have never tested the difference between the theoretical and practical flow of water through pipes. In arranging new works of supply I would rather be guided by my own observations and what I know to be the general practice of the most experienced engineers, than by any mathematical formulæ, as, from all the recorded experiments on the subject, the theoretical and practical results seem to differ so materially.

90. Will you give practical illustrations of the discrepancies between the mathematical hydraulics and actual experience?—Not having made any experiments, I cannot.

91. What additional heads of water did the current hypothesis suggest, and what did practice prove to be sufficient for sending a double quantity of water through mains of the same diameter?—The current hypothesis would suggest a much greater altitude for producing an increased flow through the same pipes than I believe would be found necessary in practice.

92. It appears to be the common practice in laying down pipe water-supplies to lay down tapering mains, trunk mains, as well as branches.

Mr. Quick. Must not those systems lead to inequalities of pressure and deliveries?—The trunk and branch mains for supplying a district are generally arranged to convey as much water as possible to central situations, and are then gradually reduced in size as they approach its limits. This arrangement produces slight inequalities of pressure and deliveries, but the inconvenience is more than counterbalanced by the saving of capital.

93. Have any illustrations of this general fact come practically under your observation?—Only in this way, that, when great additions have been made to particular portions of the out districts of a water company, it has been found necessary either to increase the size of the pipes, or to lay a small independent main to assist them.

94. Will you describe them?—The pipes are made to bear a much greater pressure than they are ever subjected to, as it is necessary to provide against any sudden recoils that may take place in the opening and shutting of the mains, or from other causes.

95. It appears, then, that from your experience the chief limitations to the power of sending double or increased quantities of water through the existing mains would be the power of the mains themselves to bear the increased head of water?—I believe that to be the only limit.

96. Then you believe that you are sufficiently aware of the strength of iron mains to know closely the limits of safe pressure?—I do; but I beg to observe that the pressure of the water is not the only thing to be considered in estimating the strength of iron mains. Much depends on the regularity of thickness in the castings, and whether the ground in which they are laid is solid or liable to sink.

97. Does not the breakage of cast-iron pipes form one heavy item of the company's expenses?—The breakage of mains, when properly laid, is not a heavy item of expense; the principal outlay for street repairs is occasioned by the sinking of the ground, and the vibration caused by heavy loads passing over the pavements, shaking the joints of the small pipes, and loosening the ferrules of the house-service pipes.

98. To what may it have amounted per cent. on the pipes laid down?—The amount has been so indefinite that no separate account has been taken of it.

99. It appears that the Grand Junction Company's works comprise the largest cast-iron main (30 inches) laid down in the metropolis?—Yes, for any great length.

100. Have you any doubt that when properly protected by air-vessels they will act as pipes of an inferior description, as appears from the remains, were made to act by the Romans in the extensive distribution of water?—I believe that air-vessels placed at intervals (particularly on the summit-levels) would be a great protection to every description of main.

101. Are there any means of ascertaining what numbers of large wells are used within your district?—Only by special survey.

102. What trades or manufacturers usually use steam-engines or large machine power?—Brewers, distillers, millers, tanners, hatters, engineers, dyers, railways, saw-mills, gas-works, potters, printers, &c.

103. What manufacturers are there who use extra quantities of water?—Brewers, distillers, tanners, fellmongers, hair-washers, hatters, dyers, gas-works, potters, printers, chemists, &c.

104. Will you look at the trades directory and see what numbers of them are indicated, and what proportion of them are situated within your district?—The Southwark Company supply upwards of 600 large and small manufacturers, and works that use extra quantities of water, many of whom have Artesian and deep wells on their premises, but prefer the river water for parts of their business; but it would require a special survey to ascertain the correct number. Mr. Quick.

105. Might not that main be broken for want of precaution?—There are several ways in which this may be done, either by opening or shutting a stop-cock suddenly, or, when under pressure, striking a sharp blow on the external surface.

106. It appears then that the greatest loss and the greatest danger to which the main and water pipes are exposed is from hydraulic jerks; now, on the constant system of supply, will not these be diminished?—The mains will be liable, in a certain degree, to the same hydraulic recoils in the two systems of supply, as it will be necessary to empty and charge them after repairs and alterations.

107. You are aware that earthenware pipes have been made which have only broken under pressures of upwards of 1500 feet, or more than 40 atmospheres?—I have been informed that such is the case.

108. What is the point of pressure at which you test cast-iron pipes? —The large trunk mains are usually proved by hydraulic pressure to a column of water 600 feet in altitude, and the smaller pipes to 300 and 400 feet.

109. Being more frangible, it may be expected that earthenware pipes will, notwithstanding their strength under steady pressure, be more exposed to hydraulic jerks?—I have no doubt this would be the case, from the difference in the cohesion of the particles of which the materials are composed; and perhaps cast iron would be assisted by the lead ring which forms the joint, and admits of a small amount of contraction or expansion.

110. Have you observed water in motion and conveying matter in suspension, and the same water interrupted in its flow so as to allow a partial settling?—I have; and found that a small current of water would keep a large quantity of heavy matter in motion; but if any interruption took place in the flow, and settling commenced, it required a considerable amount of labour, or an immense quantity of water, to set the deposit again in motion.

111. Have you observed what extra quantity of water it would take to move deposit after it has once become settled?—Much will depend on the nature of the deposit; if it is of a light, loose consistency, the same flow of water would remove it in a longer time; but if the débris from the roads is once allowed to become indurated in the drains, I do not think any amount of water, unless under immense pressure, would remove it.

112. Do you agree in the evidence of Mr. Lovick and Mr. Grant, as to the additional quantities of water that would be required to raise and remove deposit on an intermittent system of drainage, such as prevails on the Surrey side of the river, as contrasted with a constant flow produced by pumping or other means?—I perfectly agree with Mr. Lovick and Mr. Grant that great additional quantities of water would be required to remove the deposit consequent upon any intermittent

Mr. Quick. system of drainage, and I believe it would be found a greater economy, in situations like the Surrey side of the river, to receive the sewage in tanks or sumps, to be pumped into higher levels, than to pump the extra quantity of water that would be required for flushing after each deposit had taken place.

W. C. Mylne, Esq., examined.

Mr. Mylne. 1. You are, I believe, engineer to the New River Company?—I have been their engineer for about 40 years.

2. The Commissioners are desirous of knowing what is the quantity of water you have pumped in your district during the last 12 months?—The amount of water pumped in and supplied in the New River district during the last year (1849) has been estimated at about 2,109,339,311 gallons.

3. What was the quantity delivered per tenement?—The quantity delivered into London during the year 1849, when divided by the number of tenants, will average about 200 gallons each per day. I believe that is rather below the average given in the last return to Parliament. The sources from which the Company took their supply during the summer of 1849, were the Chadwell spring, which is calculated to give 500 cubic feet a minute; a supply branch from the river Lea, which is limited by an Act of Parliament to 1,340 cubic feet a minute; the well at Amwell End, from which we draw 150 cubic feet a minute; another at Amwell-hill, supplying the same quantity; a well at Cheshunt, yielding 60 cubic feet a minute; and another at Tottenham Court-road, giving 70 cubic feet a minute. These are the whole of our sources, excepting some small springs taken into the river in its course, and the water-shed of small districts collected at Cheshunt into reservoirs, and occasionally taken into the river. The town would have taken more than the above last summer if the Company could have distributed a larger supply. In June last, in consequence of the great dread from the presence of cholera, we found great difficulty in meeting the demands of the public for water, and I pointed out to the authorities at the Mansion House the circumstance that the Lord Mayor of London in 1832, when the cholera raged, applied to the trustees of the Lea for more water, and an unlimited quantity was then afforded. In consequence, a similar application was made to the trustees in 1849, and a limited quantity was granted, but at the end of a month it was withdrawn, which caused much dissatisfaction in the City.

4. Do you think that the Company would have any objection to allow the capacity of their works, and the average amount of flow of water therefrom, to be verified?—I should think the Company would have no objection whatever to the quantity being verified.

5. Have you had occasion to examine the actual consumption of water in houses of different classes?—I have. (See the annexed Table, p. 43, which shows the result of that examination.)

COMPARISON of the CONSUMPTION of WATER in the HOUSES of the Poor and those of the better Classes, as also the customary Charges for the same.

Description of House.	Average Number of Inmates, per Room.	Average Consumption, per Day per Inmate, in Gallons.	Average Quantity consumed, per Day per Room.	Charge, per Room per Annum.	Price per Head per Annum, to which the Annual Charge is equivalent.	
				s.		
1st Class, having from 12 to 20 rooms, with proper cisternage	0·658	12·87	8·47	6·	9·11	High service charge, under 50 feet.
2nd Class, houses of the middle class ditto.	1·005	7·41	7·45	5·	4·97	High service, under 13 feet.
3rd Class, houses of the poor, having receptacles for water.	2·04	3·65	7·43	3·5	1·71	Low service only.
4th Class, courts and alleys, with common cocks, supplied once a-day.	2·86	5·11	14·63	3·	1·04	Low service only.

N.B.—The preceding averages are taken from 552 houses, containing 4,319 persons.

CONSUMPTION in the Dwellings of the Poor under Improved Management.

In the Model Lodging-houses and Workhouses.	Consumption, per Day per Head, in Gallons.	Number of Persons supplied.	Capacity of Cisternage per Head.	Charge, per Head per Annum.	Charge, per Family per Annum, taken at 5½ Persons.
George-street, St. Giles . . .	6·5	104	11·13	1·67	9·075
Model Buildings, St. Pancras-road	6·12	573	7·40	1·57	8·635
In Holborn Union Workhouse.	5·0	698	9·15	1·26	6·930
St. Martin's Workhouse. . .	3·68	601	6·31	1·26	6·930
Clerkenwell Workhouse . .	3·1	433	5·39	0·92	4·972

N.B.—The preceding averages are taken from supplies to 3,458 persons. In each case the cisternage (or quantity which may at any time be used) much exceeds the supposed ordinary consumption. If the model buildings in St. Pancras-road be taken as an example of what may generally be the number of inmates in improved dwellings for the poor, 1·84 will be the number of persons in each room, and 11·26 gallons the consumption per room per diem.

6. From your experience have you had the opportunity of observing that 4-inch tubular drains keep themselves clean without an extra supply of water, and that 6 or 9-inch branch sewers also keep themselves clean?—Yes, I am of that opinion, if they have a proper inclination.

7. Have you considered the advantage of the house-service pipes being carried at the back instead of the front of the houses?—To obtain a water supply to the house-service pipes from the backs instead of the fronts of the houses, the iron service-pipes should go through the back gardens of the houses.

8. Would it not save the expense of the length of service-pipes through the front premises from the centre of the street, to get them to the place where the water is used at the back, and thus save two-thirds of the length of service-pipes?—In wide streets, where there are iron service-pipes on each side, there would certainly be a saving by the depth of the house in the length of the leaden pipes used, and no greater extent of iron required. In narrow streets, where only one line of pipes is placed in the centre, there would be a greater length of leaden pipes saved, but the extent of iron pipe in use would be doubled.

Mr. Mylne.

9. What towns have you visited where there is a constant supply? —Ashton, Duckinfield, Leeds, Nottingham, Glasgow, Edinburgh.

10. Do you think that the Ashton works are, on the whole, a fair set of works?—Yes, they are very well managed.

11. Do you not consider a pail of water as containing about two gallons?—A pail of water contains in general about three gallons.

12. It is stated, that at Preston, where there is a constant supply, the actual consumption of water is about the same as you state in the metropolis, namely, about 55 gallons?—Having only passed through Preston in my way to other towns, without the opportunity of examining the works there, I have no means of answering this question.

13. What is your opinion with regard to the advantages of the constant system of water supply?—I think that where a domestic supply is required for a moral and well-conducted population, the constant system of supply is, under certain provisions, the most efficient, and in annual cost, I conceive, the cheapest. This opinion is given independent of sanitary requirements, with the extent of which we are at present but little acquainted. To work such an establishment well, it should be originally constructed for this system of supply, and the pipes should be laid deep in the ground to avoid the effects of frost. In expressing this opinion on the constant supply, I do not support the abandonment of the cisterns and tanks in respectable dwellings; one or more in every large house is essential for closet purposes, for steam apparatus, and to meet cases of unavoidable interruption of supply during repairs. A large tank in every cluster of houses occupied by the poor is also equally necessary, from which each house should be supplied. By these means the extreme pressure upon the taps in domestic use is reduced, and much wear and tear avoided. By thus retaining the use of tanks (either in slate or iron) there is the advantage of employing less capital in pipes, as they may then be employed in discharging the supplies for a more considerable portion of the 24 hours, and be able to extend without inconvenience to the consumer (what I have observed to be practised under the constant supply system) the wiredrawing the supplies to wasteful districts, and those of very low level, for the purpose of securing a more full discharge to other portions of the town at higher elevations. The more modern the town requiring to be supplied, the better adapted to this system of constant supply, for under such circumstances the large and respectable inhabited houses are found in one neighbourhood, and the labouring classes in another, and not intermixed, as in old towns. Among the very poor I disapprove much of the use of butts; the occupants too often dip with unclean vessels into them, and thus injure the quality of the water. As to stand-cocks in the public courts, they are well known to be particularly inconvenient, as well as a public nuisance. If the Water Companies were to erect large tanks (at a small additional charge), and take the control of them, from which each house should have a pipe, the constant means of obtaining water within the premises would be afforded in these miserable localities, which exist, in a greater or less degree, in every town in the kingdom.

In the application of the intermittent supply to long existing towns, where there is that intermixture of classes referred to above,

where all kinds of trades are on the increase and in full work, and manufacturers are removing their establishments from place to place, with districts crowded with inhabitants, without regular employment, and snatching a scanty subsistence by their wits, as occasion may afford, there exists many advantages in the intermittent over the constant system of supply. Upon this subject I have already expressed my opinion in a letter to Her Majesty's Commissioners of Sewers for the City of London, which I now subjoin. Mr. Mylne.

At a Meeting of the Commissioners of Sewers of the City of London, held, pursuant to adjournment, on Tuesday, the 27th day of March, 1849,

W. A. Peacock, Esq., Deputy, in the Chair.

The clerk lays before the Court the following letters, which are severally read:—

Dear Sir, *New River Head, March* 23, 1849.

In reply to your letter of the 3rd instant, requesting to be favoured with my opinion, for the information of the Commissioners of Sewers of the City of London, as to whether any really important difficulties exist to prevent a constant and general supply of water by the New River Company, and also what in my judgment would be likely to be the effect, in a sanitary point of view, of such a supply, I beg to state, that having made various experiments with a view to ascertain the practicability of carrying out such a system in London, I feel satisfied, from the existing internal arrangements of the distributary leaden pipes and cocks, which are all private property, from the great number of open pipes, from the neglect of not having ball-cocks thereon, and from the impossibility which would, under a constant supply, exist, of complying with the occasional demand of the public for temporary large supplies, it is quite impossible for the New River Company to afford a constant and general supply to the district where their pipes are laid, and fulfil their present engagements with the public.

As I have given the subject of constant supply much consideration, and as I have visited most of the large manufacturing towns where it has been introduced, I trust I may be excused for making some remarks on the difficulty attending such a system, in connexion with the existing engagements of the Company, and upon the very doubtful advantage its introduction would confer on the inhabitants of the metropolis of England, where so little restraint exists in the expenditure of capital upon the internal domestic arrangement for the consumption of water within their dwellings.

By the accompanying section of the town through the lines of the leading mains of the New River Company, it will be seen that the demand for water to tanks in the upper stories of the houses has become so general, that the original level of the reservoirs at the New River Head is quite inadequate for affording the high supply now required by the tenants.

It also gives some idea of the nature of the demand required in the various portions of the City and its suburbs.

Now the use of water from these tanks, as also from all the other cisterns, is intermittent; it is more particularly in demand during the earlier hours of each working day; the last day in the week demands the largest supply for domestic purposes, and during the heat of summer the demand very materially increases.

Supposing, therefore, that new reservoirs are to be obtained at a sufficient elevation, and within a reasonable distance, to ensure at all times a supply to these tanks, the increase in the dimensions of the pipes, to afford a constant and regular supply to all these tenants, would be so great that the most moderate

Mr. Mylne. interest upon the required outlay on pipes and reservoirs would far exceed the interest on the capital invested in cisterns for ordinary supplies.

By the present mode of supply, where so large a portion of the tenants are provided with proper tanks or cisterns for water, the public have ample means of obtaining a general supply, and by the application of the machinery of the Water Work establishments, the supply is distributed, under such a pressure as the circumstances at the time may require, directly into and through the iron pipes, and the public also obtain, under this system, for pressing circumstances, such as fires, &c., an advantage that would be wholly lost under the system of a constant supply.

Again, in the large manufacturing towns the houses are generally freeholds, or have been erected on ground feud out to individuals who cannot be disturbed; but in London nearly all is leasehold property, and where large traders are continually removing from one part of the town to another, their newly created positions are immediately satisfied through the medium of pressure, although the pipes may be quite inadequate to such a discharge under an ordinary and fixed head.

Again, very large and necessary intermittent supplies are required during the occasional failure of private machinery, in the supply from wells, as also from increased demand to extinguish fires, where extremely combustible materials may have been collected. and thus a far more extensive supply can be given at high elevations than could be afforded under the constant supply system.

I must further state, that means exist between the Water Companies of assisting each other, through communications made between their works, and that during the last season an application having been made to the New River Company for immediate assistance, an arrangement was entered into, and in a very short time the supply of 1,000 houses was commenced and has been continued for some time through pipes only capable of affording such an accommodation under the present system of supply.

Now, to continue all these advantages to the present tenants that are provided with proper pipes and cisterns for receiving an ample supply of water, and to secure the same to all the poorer inhabitants that may be residing in houses that are not provided with the necessary means for storing water, all that is required, and which I cannot too strongly recommend, is, that tanks should be enforced upon the landlords, and also in all the courts where common cocks exist or may hereafter be required.

These tanks might be made of wrought iron: thus the inhabitants of such courts would have the constant means of drawing water; and where the landlords cannot afford to erect them, the Water Companies should provide them on the receipt of a moderate interest from the landlords, the water-rent in all such cases being also paid by the landlords; and although I cannot professionally answer the latter part of your request as to the sanitary effect of a constant supply, I am decidedly of opinion that whatever advantages would arise to the poorer inhabitants from such supply in the opinion of medical officers, such would be equally obtained by what I have here recommended in respect to the enforcement of proper tanks or cisterns being provided by all landlords.

I remain, dear Sir,
Your's faithfully,
WILLIAM CHADWELL MYLNE, F.R.S.

Joseph Daw, Esq.,
Principal Clerk, &c.

SIR, *New River Office, March* 23, 1849.

IN forwarding, for the information of the Commissioners of Sewers of the City of London, Mr. Mylne's reply to your letter of the 3rd instant, I am desired by the Directors of the New River Company to furnish the following additional information touching the rate of charge, the quantity supplied, and the number of houses that do not receive water.

Mr. Mylne.

1*st. Rate of Charge.*

On a careful examination of the water-rents paid within the City, it is found that the charge (as compared with the parochial returns of the rack-rent), does not exceed three per cent., and if the large consumers were excluded, the average rate for domestic supplies would be found considerably below this average.

2*nd. Quantity supplied.*

The average quantity of water supplied by the New River Company during the year 1848, gives for daily distribution (including the supplies afforded for sanitary purposes), a quantity per tenant equal to or more than 200 gallons. This quantity is capable of being increased in various ways, by farther outlay of capital, whenever it may be required; but even now such quantity is more than double the amount (as stated in evidence before the Health of Towns Commissioners) of the quantity delivered under the constant supply system, even at Nottingham, Preston, or Greenock, which have been represented as the standards of perfection.

3*rd. Houses unsupplied.*

In a prospectus lately put forth, it is stated that within the district supplied by the New River there are 300,000 persons unsupplied. As this appeared incredible, a strict inquiry has taken place, and the result turns out as follows, viz.:—

Old premises within the district, never supplied, and having wells or other modes of supply, or not requiring water	1,056
Houses taken off the works, not being inhabited, or not wishing to pay water-rent	986
	2,042
If five persons are taken as residing in each house, multiply by	5
Gives the number of persons unsupplied by the New River water	10,210

I also enclose, by direction of the Board, a copy of the section referred to in Mr. Mylne's letter, for the use of the Commissioners.

I have the honour to be, Sir,

Your most obedient servant,

FRED. INGLIS, *Clerk.*

Joseph Daw, *Esq.*,
&c. &c.

Ordered,—That the same be printed, and a copy be sent to every member of the Court.

JOSEPH DAW, *Principal Clerk.*

Captain Vetch examined.

Capt. Vetch.

1. Have you not given great attention to measures of sanitary improvement; and have you not been consulted from time to time with respect to the drainage of towns?—Yes.

2. And with respect to the drainage of Windsor?—Yes.

3. Have you not taken a view of the present supply of water from the Thames?—Yes.

Capt. Vetch.

4. Will you state to the Commissioners your views as to the objections to the mode of conducting the water from its sources, near Ware, by the New River, to London ?—The New River derives its chief supply of water from the river Lea, a little above the town of Ware, the amount however being limited to 1·340 cube feet per minute; from the Shadwell springs, and other sources near the same locality it has a further supply of 860 cube feet per minute, (part of which is pumped,) thus obtaining from near Ware, a total supply of 2,200 cube feet per minute, or 3,168,000 per diem. When the New River was projected we learn that the springs at Chadwell and Amwell comprised all the water intended to be taken to London at that time (1606), and probably the supply of water by these springs was then equal to the requirement. The mode of conduction adopted for the water was that of an open canal or mill-leat, constructed nearly on a level, having an inclination of only 3 inches per mile, and to avoid tunnels, and cuttings, embankments, and arcades, the leat was made to follow all the sinuosities of the ground (as on a contour line,) and similar to the mode resorted to of the rudest kind, and for the rudest purpose, but in keeping with the age and its wants, and when the work was accomplished in 1613, it no doubt conferred a great boon on the inhabitants of London, and does so still from want of a comprehensive work of art and science worthy of the present day, and equal to the requirements of the present population. Within the present century, great ingenuity and great expense have been applied by the New River Company to correct the evils of the rude and vicious mode of conduit first adopted, and little more improvement can be effected in that direction, indeed such praiseworthy zeal would be better applied to change the system entirely, but probably the very great misapplication of funds and talents to perfect in detail what was defective in principle, may have served to protract the existing works in their primitive form to the exclusion of others more capable of meeting the demands of the day. The New River or canal is about 18 feet wide and 4 feet deep, and extends from the site of the ballance-engine, at the river Lea, near Ware, to the New River Head, at Clerkenwell, over a tortuous length of about 39 miles, while the distance by a straight line is only about half as much; the water is received from the Lea on a level of about 100 feet above high-water mark in the Thames, and is delivered at Clerkenwell at 84 feet above the same, or with a total descent of 16 feet, for though the inclination of the surface of the water is graduated to a descent of 3 inches per mile, or 10 feet in the whole distance, there are some overfalls which add 6 feet more to the descent. A great objection to the conveyance of water for domestic purposes in an open earthern channel is, that the water must have a very slow motion, not exceeding half a-mile per hour, to prevent the current wearing the channel-bed, and bringing in turbid water; the slow motion is again attended with serious evils, depositions of silt and decayed vegetable matter take place, which require to be cleaned out from time to time; in the warm season, so long and broad a surface exposed to the atmosphere, gets heated to a degree favourable to the production of vegetable and animal life of the lower forms, and also in giving rise to a considerable quantity of waste from evaporation, the high temperature

of the water further facilitates the decoction of leaves and other vegetable matters, which get blown into the New River, to the manifest injury of the water, but there are other pollutions of a worse character, to which all open canals are subject. It is true the New River Company have five acres of settling pools at Clerkenwell and 38 at Newington, for the deposit of solid matters, but exposed as such broad surfaces must be to the summer heats, it may be doubted if the tendency thus afforded to the germination of animal and vegetable life and decoction of vegetable matters, do not create more evil than good. Such are the objections to all open water conduits conducted in earthern channels, the deficiencies of which will however be still better appreciated by a contrast with the qualifications that may be obtained for the same water if conveyed in covered channels constructed of stone or brick-work, and conducted in straight lines with an uniform and efficient descent, crossing valleys on embankments or arcades, and piercing hills by tunnels or adits; for example, the water of the river Lea might be conducted to London in such a channel, from Ware, at a distance of 20 miles instead of 40, and with a speed of one mile per hour instead of half a mile, that is, the transit would be accomplished in 20 hours instead of 80; and during its course it would receive no heat from the atmosphere, but, coming most of the distance in a tunnel the water would arrive as cool as when delivered from the spring; it could receive pollutions of no kind in its course, nor would it be subject to waste from evaporation; being exposed neither to light nor heat, no tendency would be crêated to germinate animal or vegetable life, to which also the increased velocity of current would serve as a preventative, and the water remaining pure, no settling tanks would be required but simply distributing basins; much greater things may however be done, for supplying London with pure water, than the mere contrast now noted. Though Sir Hugh Middleton and his successors did not hit upon the most unobjectionable mode of bringing water to London, they were certainly very near the best sources of supply; at Hertford there is a singular meeting of four copious streams of water, proceeding from chalk valleys, viz., *the Lea, the Mimram, the Beane*, and *the Rib*, which jointly have a discharge of between 6,000 and 7,000 cube feet per minute, or 9,360,000 cube feet per diem; the above streams are mainly derived from springs, one of these at Woolmers, the seat of Mr. Woodhouse, yields about 300,000 cube feet per diem, rising from or through the chalk beds, and which are perennial, clear, copious, and cool, and from some investigations instituted by the Commissioners of Sewers, it appears to me that, by means of a covered brick conduit running in a straight line from near Trinity Church, Holloway-road, to a farm-stead on the river Lea, called Watery Hall, two and a-half miles above Hertford, the several streams above-mentioned may be collected together at the latter named place, and the greater part of the water brought to a distributing reservoir at the Holloway-road, upon a distance of not more than 14 miles, and with a gradient of about 5 inches per mile, at the rate of one mile per hour, that is a quantity three times the amount of that now brought in by the New River Company, and sufficient for the supply of the whole of London north of the Thames; further, the water would be delivered without any pumping, at an

Capt. Vetch

Capt. Vetch. elevation of 140 feet above high-water mark, whereas the New River Company only deliver its water at Clerkenwell, at an elevation of 84 feet, and wherefore high service is obliged to be pumped up 60 feet.

In speaking of the New River waterworks, I wish to be allowed to add, that notwithstanding the objections which I have taken to the long, open, and tortuous channel for conducting the supply, I consider the New River Company to be the best establishment for its object in the metropolis. The sources of its supply are good; the principle of conducting the water by gravitation is good, but the manner is bad; the water delivered by the Company I conceive to be the best supplied to London, and the charges for the same the most moderate.

In addition to the streams above mentioned, as applicable to the supply of water to London, there remains to be noticed the streams of the Ash, the Stort, and springs which join the river Lea below Ware, the joint discharge of which may be estimated at 3,000 cube feet per minute, or about 4,320,000 cubic feet of water per day. Such are the resources of the river Lea and its tributaries, and which for the paramount object of supplying the increasing population of the metropolis with so needful an element of health and consumption ought to be held sacred for that purpose alone.

I beg to hand in a letter and table which I have just received from my friend, Mr. N. Beardmore, who has been investigating, with Mr. Rendel, the discharges of the streams and springs constituting the River Lea, and to whom I am much indebted for data afforded to me. From the table it will be seen that the daily yield of the conjoint waters at Field's Weir amounts to fourteen and a half millions of cubic feet, or ninety-four and a quarter millions of gallons per diem. The water was guaged by Mr. James Hunter, of Bow, as well as by Mr. Beardmore:—

RIVER LEA.

13, *Great College-street, Westminster,*
25th March, 1850.

Dear Sir,

I now beg to transmit an estimate of the discharge of the river at various points visited by you on the 10th instant. We had rather too much surplus at Ware, but it appeared we had not allowed for waste at the sluices above, which did not escape your observation.

The estimate of the run per square-mile is a method which I adopt for comparing rivers; and it is added for your use if you feel it applicable. To make this consistent, the New River and Chadwell spring are added to the observed volume at Ware, and at Fielde's Weir (the junction of the Stort), you will observe the low run of the Stort and the Ash per square mile, the enormous run of the Mimram (remarkably steady at all seasons), and the great increase of the river between the town of Ware and the Stort junction; this latter we cannot account for by any patent facts, the whole district is full of springs, and must be gaining water in all directions, for the increase is systematic in all our guagings.

I am,
Yours faithfully,

To Captain Vetch, R.E. Nathaniel Beardmore.

Capt. Vetch.

STATEMENT of the Discharge of the River Lea between Hertford and Field's Weir, March, 1850.

—	Cubic Feet per Minute.	Total Cubic Feet per Minute.	Square Miles of Drainage.	Run per Square Mile in Cubic Feet per Minute.
Discharge of Branches above Hertford.				
Lea proper at Horns Mill	2,096	..	112	18·71
River Beane at Molewood	1,483	..	83	12·42
River Rib at Ware Park.	959	..	61	14·34
River Mimram at Panshanger	1,532	..	29·3	52·39
Brooks not gauged	89	..	4·7	18·63
Total above Hertford . .	———	6,159	———	21·23
Main river at Ware Mill.	5,344	..	..	..
New River	1,250	6,594	..	..
Chadwell spring, say	506	..	..	..
Total valley at Ware. . .	..	7,100	292·5	24·27
Area to Hertford . 290 sq. miles				
Add to Ware . . 2·5 ,,				
Total . . 292·5 sq. miles				
Field's Weir.				
(81 feet above Trinity high-water mark.)				
Stort proportion	1,376	..	105	13·10
Ash proportion	480	..	44	10·90
Run at Ware, as above	5,344	..	..	..
Increase from springs between Ware and Fielde's Weir	1,100	..	..	..
Total without the New River	..	8,300	..	..
Add for New River, &c. . .	..	1,750	..	..
Total of joint valleys . . .	..	10,050	444	22·63

Note.—Fielde's weir is 81 feet above Trinity high-water mark. In the month of March, 1850 (a particularly dry one), the mean discharge of water over it was 8,000 cube feet per minute, exclusive of the abstractions by the New River; and the lock-keeper at the weir is of opinion that the discharge of March, 1850, is about what occurs in the dry months of summer.

5. Have you had any opportunities of eye surveys or any other surveys of the water-sources on the south side of the Thames?—Yes; I have especially directed my attention to the waters of the river Darenth, which discharges into the Thames, near Dartford, as I deemed it highly important in the first place, to investigate the cases of supplies from rivers discharging into the Thames, below London, the effect of which can be of little use in purging the Thames of the impurities collected in its passage through the metropolis, and which may therefore be abstracted without detriment. From the investigation made by the sanction of the Commissioners of Sewers, I find the yield of the river Darenth, near Shoreham, where its bed is elevated 148 feet above high-water mark, to be about 2,600,000 cube feet per diem, and

Capt. Vetch. which might be delivered through a brick conduit $12\frac{1}{2}$ miles long, to a distributory reservoir at Forest Hill or Manor Rise at a height of 142 feet above high-water mark. The river Darenth, like the Lee on the north side of London, is pretty constant in quantity, being chiefly fed by springs proceeding from the lower beds of chalk, or from the green sand below it; these springs are particularly numerous near Otford, but, were the conduit I have mentioned constructed, it would intercept other sources of supply, amongst others, a spring at Orpington yielding 223,000 cube feet per diem, and I estimate its efficiency would be equal to about 3,000,000 cubic feet daily for the supply of London south of the Thames. The conduits I have proposed on either side of the Thames, would be chiefly tunnels, or in miners' phrase, *adits*, in their character, and need not terminate at 13 or 14 miles, but may be gradually extended with a rise of about 6 inches per mile, which is ample, and if so continued they would, at no great distance, penetrate the green sands and wealden sands below the chalk, and so open subterranean lakes of pure filtered water for the supply of London, cool in summer and temperate in winter, a great advantage which subterranean reservoirs have over all other modes of supply. (*Handed in a map of the country, showing the sources and proposed conduits, for supplying London with water.*)

6. What do you pay for your own supply of water; and how are you satisfied with the same?—I am charged 9*l.* 12*s.* 6*d.* per annum. The supply is let on three times a-week, through a pipe about one inch in diameter; the cisterns are not capable of holding a greater supply than 473 gallons, and I find I have a quantity equal to about 14 gallons per head daily. How much the Company would supply if the cisterns were larger, I cannot tell. I am, however, sometimes disappointed in the water coming in at the appointed time; care has therefore to be taken that the cisterns are never exhausted, a precaution which limits the use of water. If the supply does not come on at the usual time, considerable trouble is occasioned in sending to the turncock, who lives at a distance; and the answer is, the water will be let on next day, or that the ball-cock or something must be out of order in the house; and as these ball-cocks seem to be made on principle to get out of order, it is difficult to tell whether the Water Company or the plumber is to blame, but between the two much inconvenience is occasioned. At times there is a considerable deposit of silt in the cisterns, and in warm weather small insects often abound, so that the cisterns require to be frequently cleaned out. All of which evils I conceive might be obviated by the system of constant supply at high-pressure; an alteration which might also save the Water Company from some abuse, that more properly belongs to builders and plumbers.

7. Have you had occasion to complain of injustice at the hands of any Water Company?—Yes. At a former residence I found out I was charged 23 per cent. higher than my next neighbour, whose house was precisely similar to my own, and a little higher rented. I complained to the Company, but after several months correspondence, could obtain no remedy. I was told by the collector at last, that they would raise the rate upon my neighbour if I insisted upon an equality; an offer which I declined.

8. What is your opinion of the usual charge for high-service?—I find it the practice of several Water Companies to charge high-service

Capt. Vetch.

whenever there is a cistern six feet above the ground-floor, which appears to me an ingenious device for charging high-service to every respectable house, however small, because if there be a water-closet anywhere but in the basement-floor, it must have a cistern six feet above the ground-floor; and Mr. Hawkesly, a good authority in such matters, states that, raising water 50 feet additional, costs but 5 or 6 per cent. outlay on the low-service, and consequently raising the water but 10 feet higher, ought only to cost the Companies about 1 per cent. on the low-service; whereas they actually charge about 25 per cent. on the same.

9. Do you recommend any other aqueducts for conveying water to London?—Yes; considering that the population af the Metropolis has nearly doubled itself in 45 years, that is from 1800 to 1845, and that great solicitude is entertained that the same ratio of increase may continue to 1890, I consider it a most important measure to secure all the best supplies of water that can be obtained near London, before they be appropriated to other objects of minor importance; and while there still exist many facilities for carrying out the necessary works which the increase of buildings in and round the Metropolis may by-and-by render almost impracticable at any cost.

10. What other are the sources which you consider ought now to be secured for the benefit of the metropolis?—I conceive, in the first place, that the water of the River Verulam is the first to be secured, and rendered available for the public good of London; the water of this river, taken a little way above Watford, is a never-failing stream, derived from springs, and yielding 3 millions cubic feet of water per diem, at an altitude of 158 feet above high water in the Thames. This beautiful supply of water may be brought to a reservoir near the Blind School, Finchley-road, within three miles of Regent-street, by an aqueduct carried in a straight line for a distance of 12 miles only, and with a descent of five or six feet, it would be delivered at the reservoir at 152 feet of altitude above the Thames, in a space of 12 hours' journey from the river. The proposed aqueduct should be cased in brickwork, and carried chiefly under ground, secure from heat and all sources of pollution. It seems the more necessary to secure this source of supply for the public benefit, as its good qualities are too well known to allow it to remain long unfingered by some commercial Water Company. Indeed there is a Bill before Parliament this year, which proposes to appropriate the same, and to drive it up by steam-power to high reservoirs at Stanmore, Elmstree, Harrow, and Hampstead, for the supply of the outskirts and country villages; whereas it may flow, by gravitation, in a fine stream, high enough for the wants of the great Metropolis, and appropriated to any other purpose would be an act of profanation.

Similar to the supplies of water on the north-east of London, which unite to constitute the River Lea, those on the north-west of London unite to constitute the River Colne, and consist of the following streams. The Colne proper, an insignificant brook in dry weather, but subject to certain floods, deriving its supply chiefly from a surface of London clay, extending from Chipping Barnet to North Myms. In dry weather the stream seems to be deposited in swallow holes of the chalk, but in wet weather the water collects in a pool, and overflows the lip of its basin, and thence joins the Verulam.

Capt. Vetch.

The Verulam, a fine stream, having a course of 19 miles through a chalk valley, is chiefly fed from springs, and is clear and constant, with an average yield of about three millions cube feet per diem.

The Gade, a fine stream, with a course of 14 miles through a chalk valley, is chiefly fed by springs, and yields a supply of about four millions cube feet per diem.

The Chess, a fine stream, flows for nine miles through a chalk valley, is fed by springs, is constant and clear, and yields somewhat better than two millions cube feet per diem.

The above streams have their waters united a little way above Rickmansworth, where their joint yield or discharge amounts to seven and three-quarters millions cube feet per diem, a great increase on the quantity afforded by them separately, but presenting a fact similar to what is observed on the River Lea at Field's Weir, the united streams in both cases showing a great accession of water from springs presumed to exist in the beds of the rivers, and which may be explained by supposing that the Lea and the Colne, throughout a great extent of their course, flow on the line of a great rent of the chalk formation, which probably extends from Widford, on the north-east, to Maplecross, on the south-west, a distance of 28 miles, and which line crosses the swallow-holes in the chalk at North Myms above alluded to.

It would be practicable, if so required, to unite the waters of the Verulam, Gade, and Chess, at a place near Moor House, about one mile east of Rickmansworth, and to convey their joint yield by a straight and covered aqueduct to the site for a reservoir already suggested near the Blind-school, New Finchley-road, and deliver the same at an altitude of 142 feet above Trinity high-water mark, and by a channel of about thirteen miles in length.

11. Will you notice any remaining sources you would suggest for the supply of water to London?—The fourth and last aqueduct which might be proposed to be applied to bring water to the Metropolis, would receive the waters of the River Mole at a point one mile east from Betchworth, above which point the river forks out into six great branches, besides smaller ones, unwatering altogether a district of strata underlying the chalk, equal in extent to about 100 square miles; and I am of opinion that the water obtained at this point would not seriously abstract from the quantity of water conveyed by the Mole into the Thames; as below the point at which it is proposed to be intercepted, the waters get seriously diminished in passing through an absorbent soil, which drinks up the supply to no beneficial purpose. The aqueduct to bring home the supply of the Mole to a reservoir on the high ground near Streatham, would be 15 miles in length, and chiefly carried under ground by a tunnel or adit, which would, as in the other cases, bring home the water cool and free from any possible means of pollution in its transit; and I estimate that three million cubic feet may be brought in as a daily supply. This last source of supply is of a very different nature from those which I have already named, and requires more investigation than I have yet been able to bestow upon it; I have therefore only to notice it as a probable source at a short distance from the metropolis, which may be advantageously made available.

12. What provision do you propose for the aëration of the water brought in by these brick conduits?—The size of the culverts will be

such as to permit a column of air, nearly equal to that of the water, passing along with it; the flow of the water would be regulated nearly at the rate of one mile per hour. Besides, at intervals there would be ventilating shafts reaching to the surface, and receptacles at various intervals for the deposit of any sedimentary or solid matter. Capt. Vetch

13. Do you propose to aid the supplies of water by means of artesian wells or *bore-holes*, or by pumping up the natural subterranean resources?—No, I should particularly avoid resorting to any such means of forcing the subterranean reservoirs; and conceive that all such expedients ought to be interdicted, as interfering with the constant resources freely offered through natural means.

14. Do you apprehend much difficulty and opposition on the part of landowners and millowners to the construction of the aqueducts you advocate?—The interference with land by the kind of aqueduct proposed would be the least possible, since very little surface ground would be required—the conduits taking generally an under-ground course, so that little more than a right-of-way would become necessary; and there would be little or no interference with the rights and usages of the surface of the land. No doubt full compensation must be made for the loss of water to those now enjoying the use of it. Were the supplies of water and right-of-way sought to be obtained for the purposes of a private company as a commercial speculation, I conceive extravagant demands would be made upon such company, and every difficulty placed in its way, and with some reason, as no one is disposed to have his rights and property taken from him on compulsion, to serve the purposes of a private speculation; but much otherwise, I conceive, would be the feelings of the same persons if they understood what they were required to part with was for the benefit of a great public measure, from which the promoters were to derive no personal benefit; feelings which I have often heard expressed on this and similar occasions. I am, therefore, inclined to believe that the owners of properties under the circumstances proposed, would be content with what would be deemed a just and proper value for their rights and properties; and this view of the subject leads me to an opinion that, it would be impossible to carry any great and comprehensive measure at any reasonable cost, for the supply of the Metropolis with water, except as a measure undertaken for and by the public.

15. Will you state what will be the length of the several aqueducts you propose, and what the quantity of water you propose to bring into London by each?—The Lea aqueduct, 14 miles long, to bring in a supply of 7,000,000 of cubic feet per diem, and deliver the same at an elevation of 140 feet above Trinity high-water mark.

Secondly. The Darenth aqueduct, 13 miles long, to bring in a supply of 3,000,000 of cubic feet per diem.

Thirdly. The Colne aqueduct; 12 miles long, to bring in 3,000,000 per diem.

Fourthly. The Mole aqueduct, 15 miles long, to bring in, from a point on the course of that river, a little way above the village of Betchworth, about 3,000,000 of cubic feet per diem.

The drainage area of the Mole above the point of interception is somewhat more than 100 square miles, and it is probable that much good

Capt. Vetch. gathering ground exists in the district, which would much increase the amount of supply.

Aqueduct.	Length in Statute Miles.	Supply of Water per diem in Cube Feet.
Lea	14	7,000,000
Darenth. . .	13	3,000,000
Colne . . .	12	3,000,000
Mole . . .	15	3,000,000
Total. .	54	16,000,000

The above supplies may all be delivered to reservoirs 140 feet above high-water mark; and while the quantity of water proposed to be taken from the present discharge of the Lea and the Colne might (if thought fit) be greatly increased, it is reasonable to believe that the prosecution of the driftways would cut open many springs, so as materially to add to the supply.

16. Do you not consider the above quantity of water as unnecessarily great?—If water can be brought to London from such short distances, and at such an altitude, on the gravitating system alone—cool, and clear in quality, I do not consider that any quantity of such water, and under such conditions, can be deemed over abundant for the health of the population; and which, at the present ratio of increase, may amount, in forty years, to about 4,000,000 of souls. The supply of water to the population of Rome at present is estimated at the rate of 5 cubic feet per person per day; but under the *Empire* we learn that the quantity actually supplied by the Roman aqueducts amounted to about 50,000,000 cubic feet per day, for the use of a population presumed to have con-consisted of about 1,000,000. Amongst the numerous grand works constructed by the Romans, for the supply of water to the capital, may be mentioned the aqueduct of *Aqua Claudiæ*, which is stated to have passed through a subterranean channel 36¼ miles in length; while that of the *Aqua Martia* is said to have entered a tunnel 16 feet in diameter, in which it was conveyed for a distance of 38 miles. These and other great works constructed by the Romans for the supply of so important an element of life and health to crowded populations, ought to serve as a stimulus to pursue the same bold tract in supplying water to the greatest city known in history—the metropolis of the British empire.

17. What is the quality of the water which the sources you have mentioned will supply?—The waters, when derived near their sources, will be remarkably free from all animal and vegetable substances; but coming chiefly from springs in seams of the chalk formation, or passing through them, I expect they would be found nearly similar to the water in the New River near Ware—that is, of 16 degrees of Clark's test for hardness; and containing about 20½ grains of earthen salts in chemical solution, chiefly *bicarbonate* of lime — conditions, no doubt, unfavourable for washing purposes, but it must be allowed that a certain amount of bicarbonate of lime is useful in preserving the water from corrupting influences, and that it renders the water more grateful to the taste; and that of the two evils (as far as sanitary objects are concerned) it is better

to have *bicarbonate of lime* than animal and vegetable matter, causing putrescence in the water. For instance, looking at Mr. Brand's analysis of water at page 102 of Sir William Clay's recent pamphlet, it will be seen that the water in the Paddington Canal at Kensal Green, (where it is supplied to some extent from the *Ruislip* reservoir, gathered from the surface,) has only a hardness of 8¾° according to Clark's test, and contains only 11½ grains of solid matter per gallon, and in these two particulars twice as pure as the water of the New River; but such water is nevertheless very filthy, from animal and vegetable contamination; and I may mention here that about fourteen months ago the following description (from good authority) of the condition of the water of a canal near London, came under my notice:—" Even when the water is clear, it is very deleterious, producing, if used for drinking, diarrhœa and large pustules on the body; but at times the water is so much discoloured from vegetable matter, that it has the appearance of tan-pit water; and the barges passing along the canal are so deeply laden, that they stir up the clay from the bottom and sides of the canal, and leave the water in a muddy state." Capt. Vetch.

18. Has your attention been called to the scheme for bringing water from the Thames at Henley, for the supply of London?—It has, particularly to the scheme of last year, which appeared to be designed for the double purpose of a navigation and a supply of water to London for domestic purposes. The scheme of this year appears more distinctly devoted to the purpose of an aqueduct, but is not very comprehensible in its arrangement, if that be its only object. Last year the scheme was avowedly one to connect the navigation of the Grand Junction Canal with that of the Thames at Henley, and was described by the promoters in February, 1849, in the following terms:— "The water will be obtained from the Henley Reach of the river Thames, and carried by an aqueduct or *waterway* 18 miles long, to the Grand Junction Canal near West Drayton, and thence in the canal (which will be deepened for the purpose), to London. This channel will be lined throughout from Henley to London, and will conduct the water by a scarcely perceptible fall of 42 inches in the whole distance—about 33 miles." Elsewhere the promoters state—" The channel between Henley and West Drayton will be navigable, and will have the effect of diminishing the navigable distance between Henley and London, by more than 20 miles. A uniform surface will be preserved throughout the whole distance; and to maintain the purity of the water, the bed of the whole channel would be formed of concrete." And elsewhere, speaking of the contamination of the water by canal purposes, the promoters state—" That objection will be removed by the reflection that 100 barges a-day can produce no effect on the vast body of water in question."

Last session it was proposed that the water so brought to London should flow from the reservoirs direct into the mains, for the supply of the lower portion of the metropolis; and that the descent of such water should be applied to hydraulic machines to force up another portion of the supply required by the higher districts of the metropolis; and the Water Companies were to be invited to become the purchasers, and to convey the water brought from Henley through their own pipes. In the Bill before Parliament it was, however, provided, that when any house was situated within 100 yards of any main of the proposed Company, the

Capt. Vetch. owner might require to be supplied from it at a fixed rate. It ought, however, to be mentioned that the prospectus stated that if the combination of navigation with a supply of water for domestic purposes should be considered undesirable by Parliament, the promoters will increase their capital by 250,000*l.*, and make a channel separate from, though parallel with and adjacent to the Grand Junction Canal; but it was not explained that the combination of the two purposes on the distance between West Drayton and Henley would be relinquished; there can be little doubt, that as a canal project, the scheme of last year was quite suitable; and if the Grand Junction Canal had been connected at West Drayton with the Thames at Henley, the object of the promoters would probably have been achieved; the proposed fall of about 1 inch per mile would have produced a flow of about half a mile per hour, quite compatible with navigation purposes, and for bringing in a supply of water for the use of the eastern portion of the canal. If the undertakers abstained from laying down mains in the streets, no calls could be made upon them for supplies for domestic purposes; and if the water Companies refrained from purchasing the waters of the undertakers, the scheme would have become solely and entirely one of navigation; indeed the mere proposal to bring the water through the Paddington Canal would have been sufficient to put that part of the question at rest.

The Henley scheme of this year is too parallel, in many of its features, with that of last session to be freed from misgivings of some connexion with canals. For instance, the proposed cut from Henley to West Drayton is to be 19½ miles long, 40 feet wide, and 10 feet deep, with a very gentle descent of 1 inch, or less, per mile; it is stated to be capable of bringing 200,000,000 gallons of water from Henley to West Drayton, daily. The continuation of the aqueduct is then to run a distance of 11 miles parallel and adjacent to the canal, in a channel only 20 feet wide and 7 feet deep. This channel is proposed to convey 100,000,000 gallons per day from the larger channel to London, for domestic purposes, while the other 100,000,000 gallons, of which the Thames is to be robbed, is to be conveyed through the canal to London, for the ostensible purpose of flushing the sewers therewith; but how it is to be distributed for that purpose, and at what cost, is not shown. But though 200,000,000 gallons of water may thus be abstracted from the Thames daily, I do not find that the smaller channel, as far as the data will allow me to judge, could convey more than 60,000,000 gallons daily. If, for sake of argument, it be admitted that the object of the promoters of this scheme is exclusively that of supplying London with water for domestic purposes, then all the objections that I have stated to the conduit of the New River will equally apply to the open channel proposed for this scheme; the motion of the water would be very slow, and in summer would promote all the tendencies to animal and vegetable corruptions, to which it would be more exposed by reason of its extensive proximity to a canal. So much for the gravitation portion of the question; but when the water is brought to Paddington, it is then proposed to pump a certain portion of it to an elevation of 268 feet to a reservoir at Hampstead. If so much pumping is required, it may be asked whether the water would not be much purer, and cheaper conveyed, if pumped direct from the Thames somewhere near Twickenham, to reservoirs at London. The great objection, however, which I take to this scheme

Capt. Vetch.

consists in the very large quantity of water it is to abstract from the Thames—about one-third of the whole quantity running over the Teddington Weir in summer, whereas the whole quantity now delivered there is not sufficient to maintain the river pure in its passage through London. The promoters of the Henley scheme of this year conclude their statement by proposing that the management of the undertaking be vested in a Board, to be selected by the ratepayers of the metropolis; but in that case it may be fairly asked why the same Board should not be allowed to select for themselves the sources of supply, and the mode of conducting the water of London.

19. If water be taken from the Thames, do you conceive it would be better to receive it at a considerable distance up the stream, as at Henley or Mapledurham; or only a short way, above Teddington Weir?—I conceive, in summer weather, if one-third of the water be abstracted from the Thames at Henley, the remainder would not reach Teddington equal in quality and quantity as before the abstraction; the volume and depth of the remaining two-thirds being so much diminished and the bed of the channel remaining the same, the velocity of the stream would be much reduced, and, from the slow motion and reduced volume, the water would get warm and evaporated to a much greater degree; the germination of animal and vegetable life would be promoted, which would corrupt and further diminish the volume of water, so that in a very dry season it is probable that only one-half the remainder would reach Teddington Weir, and in anything but a wholesome state; indeed, if such circumstances were to occur in a warmer climate than our own, an abstraction of one-half of a river, so far from the tides, would often prevent the other half reaching so far; I, therefore, consider it very important to preserve the stream of the Thames entire, cool, and clean, that its water should be permitted to flow in one united stream till at or near to the tidal compartment of the river.

20. If the water were permitted to be taken from the Thames above the influence of the tides, where do you conceive it would be most expedient to take it from?—As near above Teddington Weir as local circumstances would permit; and as the supply of water to the Thames must, to a considerable extent, be pumped, whether abstracted at Mapledurham or Twickenham, it would be an important point to reduce the expenditure of steam-power, in lifting the water, as low as possible, and for that purpose getting rid, to the greatest extent, of friction to the pipes conveying the waters to the reservoirs for distribution; and, looking at the problem as a miner, I have little hesitation in prefering the principle of action propounded by Mr. Philip Taylor in 1824, who proposed to supply London with pure water from the Thames at a point to be selected near Twickenham, and conveying it thence in a brick culvert or tunnel for nine miles, until it reached the site of appropriate reservoirs near Hampstead, up to which it would be pumped perpendicularly through shafts provided for that purpose, by powerful engines on the Cornish principle; and he justly stated, that the forcing water through a great length of iron pipes up inclined planes, was attended with so much friction, that one-fourth of the expense would be saved by a direct perpendicular rift; but how much of the saving would be due to the superior kind of engine, and how much to the diminished friction, did not exactly appear. There can be no doubt, on Mr. Taylor's plan, the steam power could be used with the best effect,

Capt. Vetch. and with no other friction from pipes than those constituting pumps: approving of Mr. Taylor's principle, probably the details might be improved upon, though I sincerely trust, that be its merits what they may, they will not form a sufficient inducement to use the water from the Thames for supplying the metropolis, until other and better sources have been found insufficient.

21. What objections have you to taking water from the River Thames above the tidal range for the supply of London?—There appears to me many important objections to abstracting the Thames water if to be obtained in a sufficient quantity from other sources. First, I conceive the purity of the water of the Thames between Battersea-bridge and Blackwall to be essential to the sanitary condition of the population located on its banks; that for many years I conceive it has been becoming more impure; and that its safety from a worse fate is chiefly due to the amount of fresh water delivered daily over Teddington Weir into the tidal compartment of the river; that the increasing impurity of the river, in the section alluded to, is manifest to many who have had occasion to observe it; nor can the fact be denied, since, through the constant increase of population, the refuse delivered into the river must be in the same proportion, while, on the other hand, the quantity of water abstracted, both above and below Teddington, by water companies has diminished more and more the amount of the diluting and scouring fluid, leaving the remainder more and more charged with foul ingredients. For sake of argument, let it be supposed that the whole stream of the Thames which is now delivered over Teddington Weir were abstracted, what would be the consequence?—The tides would then return on the flood precisely the same quantity they took away on the ebb, and probably the very same water; and it is easy to conceive, under such circumstances, how soon the state of the river would become insufferable. Now, if taking away the whole would constitute so palpable an evil, taking away one-half or one-third would only be creating an evil less in amount in these proportions; or we may put the question in another point of view—suppose that in lieu of a moveable dam of tide water at Blackwall, there was a solid weir there, and that no fresh water was delivered at Teddington into the fresh water lake, so created and extending from Blackwall to Teddington, it would be manifest how soon such a lake would become thoroughly foul and pestilential, and in either case it must be seen how vast is the importance to London, that the volume of water delivered at Teddington should be preserved *intact*: the quantity delivered in summer weather amounts to about three million cubic yards per diem, while the contents of the lake, which has just been assumed as extending to Blackwall, may be estimated roughly at 130 millions of cube yards, and therefore requiring 43 days' delivery for its entire replenishment; but if we were to suppose one-third of the supply to be taken away above Teddington, it would require 65 days to replenish the lake. The health and comfort of the Metropolis, I conceive, so materially to depend on keeping what may be called the fresh water tidal department of the river (or that extending from Teddington to Blackwall) as pure as circumstances will permit of, as to impose the necessity of obtaining our supplies of water for domestic purposes from every other source rather than the river itself; and I think it may be shown that the waters which the Lea and the Darenth rivers discharge into the Thames below Blackwall yield about 17 millions of cube feet per day,

or more than double the quantity now supplied to London. Further, I conceive that were the bed of the Thames below Teddington deprived of its usual supply of land water, it would gradually silt up, and that the navigation downwards would become seriously injured. I object to taking the water of the Thames for the use of the Metropolis, because as good or better may be obtained at a much higher level and shorter distance off; and that, were all other circumstances indifferent, the water of the Lea is to be preferred to that of the Thames. From the River Lea, at a height of 148 feet above Trinity mark, and at a distance of only 14 miles from the skirts of London, a large supply of water may be obtained; whereas the height of the river Thames at Mapledurham is but 112 feet above Trinity mark, and at a distance of 40 miles from the outskirts of London; so that for Thames water we must go three times the distance and receive the same at an altitude less by 36 feet. Capt. W[illegible]

22. Are you not aware, that in the northern districts of England the practice is extending of taking the surface waters for the use of towns?—I am aware that of late years the system is extending of storing surface waters for the supply of the northern towns, and that there are now several Bills before Parliament for such purposes. The plan pursued appears to be that of throwing dams across upland valleys, and so forming artificial lakes, and storing rain-water that would otherwise run to waste, the method is similar to what has been extensively resorted to in this country for the supply of water to our canals, and which I have seen practised in foreign parts (where the rains are periodical), for the supply of towns, farms, and factories; and where the necessary tanks are deep and extensive, the water is preserved clear, and is often superior to river water.

23. Have you had opportunities for observation, as to the surface for gathering grounds within 20 miles of the metropolis?—The surface strata within 20 miles of London are generally of an absorbent nature, being chiefly composed of beds of chalk and sand, which readily receive the rains and convey them to subterranean reservoirs. The portions of retentive soils within 20 miles of the metropolis, such as the blue and plastic clays of the London basin, as far as my observations go, are of limited extent, and being in the vicinity of arable land and a thick population, not available to any important extent of the object in view, and thus, though the strata within 20 miles of London are well stored with subterranean waters, which may be obtained by driftways, the surface is not favourable, in my opinion, for the storage of rain-water: there is, however, no doubt that much water that now runs to waste in winter may be saved for summer use, by throwing dams across some of the deeper valleys drained by the tributaries of the rivers Lea and Colne, and where, if even leakage should take place in reservoirs so formed, the escape of water would serve to augment the supply of many useful springs elsewhere. I am induced also to believe, though I cannot speak decidedly, that considerable quantities of water might be stored on the area drained by the Mole and its tributaries above Betchworth.

Henry Marten, Esq., examined. Mr. Marten.

1. You are, I believe, an engineer?—I am.
2. With whom did you serve your time?—With Mr. Wicksteed, the

Mr. Marten. engineer of the East London Water Works; whilst with him I assisted in the construction of the Hull Corporation Water Works, and was afterwards appointed by him to see his plans carried out for the construction of the Wolverhampton Water Works.

3. Since their completion have you had those works under your charge as resident engineer?—I have.

4. Will you describe the works?—They are situated at Tettenhall, a small village about 2 miles from Wolverhampton; the supply is drawn from the new red sandstone formation, and is forced from a depth of about 120 feet below the surface of the ground, over a stand-pipe 180 feet in height, the top of which is about 100 feet above the highest part of the town. They were commenced in 1845, and were wholly constructed, both in their mechanical and distributory arrangements, for carrying out the principles of the intermittent supply.

5. What is the quality of the water?—Since we have been giving a supply there has been no analysis of the water made, but the Wolverhampton Company originally decided upon it in consequence of its having been found by Mr. Aikin to be the best of 12 samples from the neighbourhood. Sandstone-water generally ranges from 16 to 21 degrees of hardness; and, as Mr. Aikin stated this to be singularly free from carbonate of lime, I believe it to be of a good average quality.

6. Has there been recently any change in the mode of water supply? —Yes. The intermittent system continued in force about 2 years from the time of opening the works early in 1847, but the company found the encouragement they met with under this system so extremely limited, and the objections raised against it so numerous, that they at length determined to abandon it; and early last year they introduced the method of constant supply. The change has met with decided success; and, to show the unpopularity of the intermittent system of supply, although the houses within the district commanded by these works number upwards of 7000, yet, during the period the company endeavoured to urge its adoption, they did not obtain more than 600 customers, or an average of 26 per month. On the adoption of the constant supply, however, an immediate increase took plaee, so that, in the 12 months during which it has been in operation, our customers have increased from 600 to more than 1750, or at the average rate of 96 per month. I should observe, that although the system of constant supply was introduced early in 1849, yet, being tried as an experiment only, it was not officially announced until the 1st of January this year. Notwithstanding this disadvantage, however, the ratio of increase under this system has been 270 per cent. greater than under the old plan. The above facts may be taken as a fair test of its superior adaptation to the domestic wants of the public. The non-success of the intermittent system is not attributable to any want of canvassing, as every house in the district was visited during the time it continued in force, and great exertions were made to obtain customers.

7. Will you state some of the particular facts with regard to the intermittent supply which came under your notice, and which led you to adopt the constant system?—We found that people felt little inclined to go to the expense and inconvenience of erecting tanks in which the water was to stagnate during the greater part of the day, when, with a little extra exertion, they could always draw a constant supply fresh from the pumps. In many places, in the more densely populated parts

of the town, there was no room on the premises for the erection of a tank, and when, in consideration of these circumstances, the company did not enforce the rules in this respect, it was found to be a great inconvenience to wait the particular times and seasons when the water might be turned on. In this case also the necessity of making use of the various domestic vessels (which could ill be spared) to hold the day's supply was felt and complained of as a hardship. The intermittent system also gave great dissatisfaction in those districts which did not receive their supply until the afternoon; these complained that they did not obtain the same advantage as their more fortunate neighbours, who received their supply in the morning. These instances illustrate the principal classes of objections raised against the intermittent system, and all of which more or less retarded its progress, and at last led to its abandonment. Mr. Marten.

8. Then, commercially considered, looking solely at the interests of a new Company, the intermittent system of supply for such a district is erroneous?—Decidedly so; in some towns, where it is exceedingly difficult to obtain good water, this system may no doubt have met with general adoption; but in a town like Wolverhampton, built upon the sandstone, and where water of a tolerably good quality may be obtained at a moderate cost, it can never succeed, the public will not be troubled with it. In the one case the public must, from necessity, put up with the supply provided; on the other it is a matter of choice whether they take it at all. I found that under the intermittent system parties only took the water where they could not do without it, whereas, under the constant system, they are often supplied for convenience sake, where there are good pumps and soft-water cisterns on the premises. Another inconvenience attaching to the intermittent system of supply arises from the water during the greater part of each day lying stagnant in all the sub-mains or service-pipes; this is a matter of material importance in all water which does not readily precipitate a protective coating on the inner surface of the pipes, as, upon being confined a short period, it acquires a disagreeable taste, and becomes highly discoloured by the absorption of a quantity of oxide of iron; this is especially the case in sandstone-water, and is a cause of much dissatisfaction, and requires, under the intermittent system, that the services should be washed out every day before the supply is given to the houses. This, of course, occasioned a great and useless waste.

9. Has it not been argued that this stagnation of the water in the pipes under the intermittent system is an advantage rather than otherwise?—Yes; it has been stated that "the pipes then become additional settling reservoirs." (See answer to question 4515 in Evidence before Health of Towns Commissioners, 1st Report.) Setting aside the fact that water so impure is actually so supplied as to require additional settlement, stagnation in the pipe will still be of no avail, as, if the pipes *are not* washed out previously to each supply, the whole of the sediment must be again stirred up by the incoming water, and driven into the tanks of the houses to be supplied. If however the pipes *are* washed out, the whole advantage of the settlement is likewise lost, as the fresh water from the mains in driving out the sediment will likewise drive out the clear water with it, and its place and the consumers' tanks will be supplied with water in which the process of settlement has still to be

Mr. Marten. completed. No advantage therefore can possibly be derived from the intermittent system on this ground, even in those waters where a temporary stagnation may not be a material evil. At Wolverhampton I found this a great disadvantage.

10. Before the change in the mode of supply took place, what was the daily rate of consumption?—The average gross consumption under the intermittent system was 128 gallons per house per diem. By gross consumption is meant the daily average of the whole quantity of water delivered and distributed amongst the tenants of the company independently of the purpose for which it is used. It includes therefore not only the domestic supply, but the proportion used by large consumers, brewers, manufacturers, &c., and the quantity used for street-watering, sewer-flushing, and waste. Hitherto in comparing the water supply of one town with another it has been customary to refer to the gross average consumption as a standard to test the relative merits of the "domestic supply." This however can never be ascertained by a comparison of the gross consumption, as the domestic supply proves but a small item in the quantity, and a town with a very much larger gross consumption may not receive nearly so good a domestic supply as one in which the gross consumption is much less. Thus, for instance, the gross consumption supplied by the London companies is very large, larger I believe than in any other town in the kingdom. The domestic supply however by no means follows the same proportion; and I believe, on the proper deductions for large consumers, waste, &c., being made on the gross consumption, it would be found that there are many provincial towns which receive a very much better domestic supply. From various observations I have been enabled to make, and the accurate accounts kept at Wolverhampton of the water delivered, I estimate the gross consumption of 128 gallons per house per diem may be divided into the following items:—

	Gallons.
To street-watering and town purposes . . .	20
To trades and large consumers	42
To washing out service-pipes, waste in houses, &c. .	31
To "domestic supply" (that is, to water actually *used* for various domestic purposes) . . .	35
Total	128

11. What has been the rate of consumption since the change?—Since the change the average gross consumption has been gradually decreasing, and during the last three months has not exceeded 79 gallons per house per diem, thus presenting a decrease of 39 per cent., as compared with the consumption under the intermittent system. This great decrease is doubtless partly owing to the water required for street-watering and for town purposes, and for trades and large consumers, not having increased in the same ratio as the number of houses.

Of the total decrease of 49 gallons per house per diem, I estimate that 22 are due to this cause, and allowing the same amount of water to be actually used (35 gallons per house per diem) for domestic purposes, under the present as under the intermittent system, the saving of waste

in the domestic consumption, washing out pipes, &c., will be 27 gallons per house per diem. Mr. Marten.

The following statement shows the amounts due to the various items of consumption under the constant system, which make up the total gross consumption of 79 gallons per house per diem.

	Gallons.
To street-watering and town purposes . . .	7
To trades and large consumers	33
To washing out service-pipes, waste in houses, &c.	4
To "domestic supply," that is, to water actually used for various domestic purposes	35
	79

12. Will you state some of the particular causes of waste which you found to accrue under the intermittent system?—When the supply was intermittent people drew much more than they actually required, in order to meet any contingency that might arise before the next supply came on. Now, however, having the water always at command, they draw only the quantity really necessary for domestic purposes. Ball-taps also would frequently stick and be out of repair, so that the water would be running away full bore the whole time it was turned on. The common practice of leaving the taps open, so that parties might have the first intimation of the water being turned on, was also a great source of waste, the taps being frequently neglected. At the Hull Water Works, constructed on principles similar to these, but where the intermittent system of supply is still continued, this is found to be very much the case. The engineer, writing on the 26th December last to the 'Hull Packet' in reply to some complaints as to the insufficiency of the supply, states that "in the summer-time it (the water) is turned on at 6 A. M., but later at this season, as the inhabitants are not up to receive it at that time, and leave the taps running to waste *for an hour or more* before they get up; even as it is, a great quantity of water is wasted in this manner." This, like the stagnation of the water in the pipes, has also been urged as an advantage afforded by the intermittent system, inasmuch as the surplus will tend to keep the drains and sewers in a clearer state. A due consideration of the circumstances affecting the water supply and sewerage will, however, prove that no advantage is derived on this score, as, when the sewerage is perfect, the quantity of water used under the constant system will be ample to keep the drains free from deposit, and where the sewerage is defective, as is unfortunately the case in most towns in the kingdom, a wasteful supply is only a great public nuisance.

13. What is the class of houses you supply?—We supply houses of all classes, but 50 per cent., as in all manufacturing districts, are under 10*l.* rental.

14. What is the proportion of trades to large consumers?—At the time we adopted the constant supply system, the trades and large consumers numbered about 20 per cent. of our customers; they now number 16 per cent.

15. Did not the former excess of water running to waste very much add to the dampness of the town, as there are no dains in Wolver-

Mr. Marten. hampton?—Yes, very much so, especially in the small ill-paved and ill-drained courts attached to the houses of the lower class. The constant opening of the cleansing plugs in the streets where there were no good gutters or sewers was very inconvenient.

16. Will you describe whether any serious difficulties or obstructions have been found in making the changes?—I have found no serious difficulty or obstructions in introducing the constant-supply system.

17. Will any alterations or additions be necessary in the pumping department?—Yes, in this department it will be necessary to construct an elevated reservoir, our head to supply the town being at present obtained by forcing the water over a high standpipe only. This, in principle, is exactly similar to a minute reservoir, capable of holding a few gallons only instead of one or two days' supply, but is subject to many practical inconveniences. The supply of the town, in this case, depends entirely from minute to minute upon the mechanical perfection of the engines, and the care and steadiness of the men employed to work them. The springing of a single bolt, or a very slight accident to certain parts of the machinery, may, in this case, entirely suspend the supply of the town for a very considerable period. The standpipe system is also a very expensive plan, the engine having to be worked, or to be in constant readiness to work, at a moment's notice, both day and night. This is necessary not only under the constant but under the intermittent system of supply, because, although all the houses may be shut off, the pressure has still at all times to be kept up in the mains to give a supply in case of fire. It is necessary on this account to employ a double set of enginemen and stokers, and to incur expensive overtime when any little repair has to be executed. To show, also, in a still clearer light the expense of the standpipe system: at these works the engine is of sufficient power to raise the whole supply for a week's consumption in 30 hours, whereas, by having no other elevated storage-room than that contained in the standpipe, the engine is obliged to be worked during 168 hours to deliver this quantity. With a standpipe only the speed of the engine has to be altered and regulated with every variation of the draught on the mains. And again, although the mains are constructed to deliver a very much larger quantity than the engine can pump at any one time, the parties supplied can derive no advantage from this, as they can never draw the water faster than it is pumped. Thus the standpipe system limits the variations of draught that can take place in the mains to the speed of the engine, instead of the velocity due to the head to which the water is actually raised. The expense and inconvenience of the standpipe system was found to be so great at these works that it was determined to construct a reservoir, even had the company contemplated continuing the intermittent plan of supply; and wherever the construction of an elevated reservoir is possible, and there are very few cases in which it is not, preference should be given to this instead of the standpipe.

18. What alteration did you find necessary in the distributory department?—I find that very little alteration is necessary. The leading main laid down for giving the intermittent supply will be amply sufficient for giving the constant supply. The capacity of the submains and services will also be ample; these latter were all calculated for delivering the whole of the day's supply in the very small period of the 24 hours, and there can, therefore, be no doubt but that they will be

Mr. Marten.

sufficient to deliver the less quantity required by the constant supply, especially when its delivery is spread over the whole day. The only material alteration I propose making in this department is to connect as many of the present dead ends of the pipes as possible, so as to keep up a free circulation. The advantages of this alteration will be more readily seen by considering the plan at present adopted in laying down water-pipes for the supply of a town. The line of the principal main having been marked out, the submains and services are branched out from it in various directions like the boughs of a tree from the main trunk. The consequence of this arrangement, which is a necessary evil under the intermittent system, is, that a great many dead ends are formed, in each of which there is constantly a quantity of water stagnating, which soon becomes unfit for use, and must be washed out at a great waste of water.

19. You state that the mains laid down for giving an intermittent supply will be amply sufficient for giving a constant supply: have you made any experiments on this point, relative to the draught on the mains at Wolverhampton during various periods of the day?—I have lately done so, and present the results of these experiments in the following table, which is also confirmed by the results of a similar series of experiments conducted in other towns in whcih the constant supply is in operation.

The first column shows the period between which each observation was made; the second the percentage of the whole "gross consumption" for the twenty-four hours delivered between those periods; and the third the number of hours which would be occupied in delivering at that rate the whole consumption for the day.

The results stated in the table are the average of a series of observations extending over the period of one week.

Time.	Percentage of gross consumption.	Time which would be occupied in delivering gross consumption.
Between 6 and 7 A.M.	3·735	26·77 hours.
" 7 " 8 "	5·209	19·19 "
" 8 " 9 "	6·192	16·14 "
" 9 " 10 "	6·438	15·53 "
" 10 " 11 "	7·076	14·13 "
" 11 " 12 "	7.764	12·88 "
" 12 " 1 P.M.	5·995	16·68 "
" 1 " 2 "	5·946	16·82 "
" 2 " 3 "	6·388	15·64 "
" 3 " 4 "	7·862	12·72 "
" 4 " 5 "	5·209	19·19 "
" 5 " 6 "	6·290	15·90 "
" 6 " 7 "	3·685	27·13 "
" 7 " 8 "	5·012	20·00 "
" 8 " 9 "	3·047	32·81 "
" 9 P.M. 6 A.M.	14·152	68·26 "
	100·000	

From the above table it appears that the greatest consumption takes place between eleven and twelve in the morning and three and four in the afternoon, during which periods the draught reaches to nearly 8 per cent.

F 2

r. Marten. upon the gross consumption, and would require the mains to be of a capacity to deliver the whole supply for the twenty-four hours in twelve or thirteen. The greatest draught takes place on the Saturday, when there is the most general cleaning up. On the forenoon of this day, between eleven and twelve, the draught reached to nearly 11 per cent. of the day's consumption, which would require the mains to be of a sufficient capacity to deliver the whole consumption in a little more than nine hours. This is the greatest rate of consumption observed. Now, under the intermittent system, it has been the general practice to lay down the mains of sufficient capacity to deliver the whole day's supply in six or eight hours, so that they will be amply sufficient under the constant system, even when the draught is at the greatest.

20. You are of opinion also that, with a free circulation, less oxidation goes on?—Yes; oxidation appears to take place in proportion to the length of time the water lies stagnant against the sides of the pipes; but by the proposed arrangement, the whole of the pipes being connected together wherever possible so as to form a great network, a free circulation is kept up, the water always tending in all the pipes to the point of greatest draught. Thus, also, a *uniform quality* of water is maintained throughout the whole town, and the pipes, being fed at both ends, may be made proportionably smaller.

21. You think, therefore, that it is very important to have the circulation active?—Yes. It presents many advantages, and in those cases in which I have applied this method it has answered admirably.

22. Is there any other alteration you propose making in this department?—I propose to make the guard-cocks on the submains and services much more numerous than under the intermittent system, placing them at an average distance of not more than 50 yards apart; all the cocks should be double-faced, so as to shut off the water either way. This arrangement overcomes a difficulty that might sometimes prove of consequence, were the constant supply given through the old intermittent pipes, as in this case the repair of a single pipe, or the laying on of one fresh house, might occasion the stoppage of supply to an extensive district. Under the proposed arrangement, however, this will not be the case; as, by shutting down the guard-cocks on either side of the place where it might be necessary to execute any repairs, &c., the tenants in the immediate neighbourhood only would be deprived of the waters, and could in no case have to go more than a few yards to obtain a temporary supply. The remainder of the district would of course be supplied through the other ends of the pipes.

23. What will be the cost of the proposed alterations?—The cost of the above-mentioned alterations, for giving the constant instead of the intermittent supply at Wolverhampton, will not exceed 6*d*. a-head of the population within the district. This is exclusive of the reservoir, which would have been essential to the continuance of the supply under the old system; including this, however, the whole cost will not exceed 2*s*. per head of the population. I think there are very few towns in which the cost of the alterations necessary for the introduction of the constant-supply system will exceed 2*s*. per head of the population, and that in general it will be found much under this amount.

24. What would be provided under that charge of 2*s*. per head?—Where none have been previously provided it will cover the expense of

providing the necessary reservoirs and the alteration of the street-mains, with the introduction of the additional stop-cocks, and will be sufficient to prepare all the internal house-fittings for the reception of the constant supply. In almost all towns in which the intermittent supply is in force, the fittings are in a very defective state. The water being on so short a time, it has been thought hardly worth while to see that these are kept in good repair; and consequently they will, as far as the taps and stop-cocks are concerned, require almost a complete renewal. The useless piping and tanks and old metal, however, which may be removed on the introduction of the constant system, will more than pay for these matters. Mr. Marten.

25. Will the additional outlay above mentioned increase the cost of raising and distributing the water and the charge to the consumer?—No. Had the works at Wolverhampton been constructed at first with a view to carry out the constant system, there is no doubt they could have been made at considerably less cost, as it is, however, the additional outlay will not require any increase of charge to the tenant. The interest of the money so spent will be fully saved in the reduction of the enginemen and turncocks' wages-account, in the smaller consumption of engine-stores, in having to pump less water, and in being enabled to deliver it in less time by having a reservoir, and by the reduced wear and tear of the cocks and pipes. There will also be a great economy in all future extensions of pipes.

26. You state your belief that the wear and tear of street-cocks will be less under a system of constant supply. Have you observed any difference in the wear and tear of these in streets of much traffic compared with those of little traffic?—I have not observed any perceptible difference between the wear and tear of the valves of cocks placed in a street where there is much traffic as compared with the *valves* of those placed in streets of less traffic; but in the former case the iron boxes which cover them are more subject to injury, and we find them sometimes filled with dirt or "sludge" from the road.

27. Supposing the levels to be the same, will not the strain and damage of pipes and taps from the hydraulic jerks be greater on the intermittent than the constant supply system?—Yes; because under the intermittent system the whole pressure of the works is brought to bear upon one particular spot with a suddenness which often causes considerable damage from the recoil. Under the constant system, however, the pressure will only vary by imperceptible degrees, and there can be no jerks on the mains and pipes. In the houses none of the common bib-taps should be allowed to be used, but should be of the kind termed "screw-down," as they are every way better adapted for high pressure, and do away with all recoil.

28. What are the variations in height, or different heads of pressure, at which the supply is delivered at Wolverhampton?—The greatest pressure is about 200 feet, and the least 100 feet.

29. What is the size of the highest house where the delivery takes place?—The South Staffordshire Hospital, which contains accommodation for 200 patients, is the highest house in which the supply is given, the top of which is about 80 feet below the top of the standpipe.

30. It appears that Wolverhampton varies in level. Have you found any occasion to "withdraw the supplies to wasteful districts, and those

Mr. Marten. of a very low level, for the purpose of securing a more full discharge at other portions of the town at high elevations?"—No. I do not understand the term "wasteful districts:"—waste and leakage imply want of repair; and when this is the case, these districts should at once be put into a proper state for receiving a supply, and not attempt a half measure by wire-drawing. When all the pipes and taps are in a proper state of repair, as they should be, the draught on the mains under the constant supply is exceedingly regular. Wire-drawing might be necessary where the constant supply is given through the old fittings erected under the intermittent system, and from which the leakage must be very great.

31. Are any, and what expedients used to adjust the pressure and rate of delivery where there are considerable variations in the heights? —I have not found it necessary to make use of any particular expedients at the Wolverhampton works to adjust the pressure and rate of delivery, excepting that in the lower parts of the town where ½-inch service-pipes are inserted, in the higher parts ¾-inch are used. A stop-cock is inserted in each house service, so that, if any inconvenience should be felt from the pressure being in any part too great, the rate of delivery can be reduced by partly shutting the cock.

32. Under the constant supply would there not be various advantages in using the hose and jet for washing the surface of the streets and house fronts?—Yes, it could be very readily applied, and would be very effective where the paving is good, in washing the surface of the streets and the footways. We occasionally wash down the front of a large inn in the market-place in Wolverhampton in this way, and it answers very well, completely removing the dirt.

33. Then you have no reason to doubt that by the use of similar means the whole face of the houses in a town might be changed from an appearance of dirt to cleanliness?—No doubt they might be washed in this way.

34. Have there been fires in Wolverhampton where these jets have been used?—It was used at one fire, and by its ready application and the great force of the water, was the means of preserving a large amount of property from destruction; it did its work so completely, that the owner afterwards informed me that he thought the water had damaged his property rather more than the fire.

35. The jet then was even more than adequate?—Yes. We found, on trying some experiments for the satisfaction of a Birmingham fire-office, that we could throw the water from a jet-pipe half as far again as it could be thrown by the fire engine, which it took 14 or 15 men to work. We can throw the water about 70 feet from the ground with a ¾-inch jet.

36. What is the expense of the service-pipes as now laid down on the constant system of supply as compared with the expense to tenants arising from cisterns, &c. under the intermittent system?—I find the cost of laying down the lead service-pipes from our mains in the streets into the houses, together with the cost of stop-cocks, bib-taps, &c. for giving the constant supply, averages 16*s.* 6*d.* per house. This is the average made upon 600 houses laid on by the Company, and taken consecutively as the entries appear in the Company's books, the total cost being 491*l.* 12*s.* Had tanks been required to these houses as

under the intermittent system, the extra cost would have been at least 22*s.* 6*d.* per house. The extra cost, therefore, on this head, of which these houses are disburdened by the introduction of the constant supply, is 675*l.* Whence from the above facts it will appear that the cost of laying on under the intermittent system is 136 per cent. greater than under the constant supply. Mr. Marten.

37. What is the smallest sized pipe you use?—I have not been in the habit of using anything smaller than $\frac{1}{2}$-inch, although I know such to have been the case at other works. I find a $\frac{3}{4}$-inch branch main more than ample to supply courts containing 13 houses.

38. How many do you think you have supplied from a $\frac{3}{4}$-inch main?—I do not remember an instance of more than 13 having been supplied from a single $\frac{3}{4}$-inch pipe, but I should not hesitate to supply 20 from the same pipe.

39. Under the old system of supply, what sized pipe should you put down for the service of courts like this you have mentioned?—I cannot say what would have been the requisite size in this case, as under the intermittent system many parties left their taps running the whole time the supply was on, so that, to give all a due supply, the pipe would have been required of considerable dimensions. Under these circumstances it is the practice to lay down a $1\frac{1}{2}$-inch or 2-inch pipe for the intermittent supply.

40. Have you used iron service-pipes instead of lead?—Yes, occasionally; but I do not prefer them, as I have found them more uncertain and more liable to damage from frost than lead pipes. They are not so readily fixed as lead, and in some situations a rapid and destructive corrosion takes place which eats them through. I have seen some iron tubing glazed on the exterior, but the cost is considerably increased in this case.

41. Will you state what would be the expense of cisterns for first-class houses with water closets, and the cost to tenants of each class of house for butts?—I have no means of telling precisely the average cost of cisterns, &c., to each class of house, but it will vary from 1*l.* up to 50*l.* or 60*l.*, in accordance with the size of the building and the completeness of the fittings.

42. Will you contrast the expense of outdoor tanks, &c., with such a system as that of Ridgway's fountain sinks, supposing them carried into the interior of each room?—A Ridgway's fountain sink might be fixed complete in each room of a house for the same sum as is now often spent in the erection of the cumbrous apparatus required under the intermittent system.

43. Also in the case of first-class houses, whether baths and fountain sinks might not be put up at the same expense as these tanks and other external apparatus?—I think so. The expense of tanks, &c., in houses of this description is often very great, and they are obliged to be placed in such out of the way positions that the expense of repairs and cleaning becomes considerable.

44. Have you had opportunities of observing the liability of the water to pollution from exposure to soot and dirt?—Yes. Where the tanks are situated within the house, the water soon loses its freshness and acquires a slimy character, and when exposed outside it rapidly accumulates on its surface a coating of the impurities invariably carried in

Mr. Marten.

the atmosphere of towns. In some waters exposed in this manner, fermentation quickly appears to take place, succeeded by an unwholesome vegetation, and lastly, the development of animal life. Filtration may clear this water, but cannot restore it to its original state. In the summer time, and during warm damp weather, water exposed in butts becomes rapidly foul, and this takes place quicker in old than new tanks. I know an instance in which a butt supplied on the intermittent plan, although washed out three times a week, yet could not be kept clean; at the end of the second day a green scum had risen to the surface of the water, and there were a quantity of little red worms, and I was informed that several other tanks were worse than this. This occurred in the neighbourhood of London. At Wolverhampton, I have observed a thick yellow scum like floating sponge given off by the water when retained in tanks, and the water has acquired an unpleasant taste. In some situations water is rendered still more unhealthy by its power of absorbing noxious gases, so that people not only live and breathe in a poisonous atmosphere, but are also required to drink it condensed in the water.

45. Since the change of system have these complaints ceased?—Yes.

46. You have met with little real occasion for the retention of tanks?—No. At present I only retain them for waterclosets, which need never be more than boxes about 18 inches square and 1 foot deep. The object of these is to cut off any direct communication between the main and the soil-pan, so as to prevent the possibility of any drawbacks. In the supply of boilers, &c., where there is no underground cistern or jacket-pit, I also require them. I do not think they need be retained for any other purposes.

47. In respect to the distributory apparatus, what sized pipes would suffice, in your opinion, for street service?—As regards capacity, I think that 2-inch pipes would be sufficient, but I never lay less than 3-inch, as there is scarcely any difference in the cost of these and the smaller size. This size also leaves a margin for the supply of any parties who may require a large consumption after the pipes are laid.

48. Did you lay down the pipes in the centre of the streets?—No; we have generally had to occupy either one side or the other, in order to leave the centre of the road for the construction of the intended sewers.

49. Will you estimate what the cost would be if you carried the pipe close to the house instead of the present system?—Supposing the case of houses in a street of an average class, say roadway 30 feet wide, with footpaths 6 feet wide, and the houses of 21 feet frontage, and 30 feet deep to the wash-houses. Then I estimate the cost of laying down the cast-iron service-pipe in the centre of the street, with cocks, fire-plugs, &c., complete, and the cost of a ¾-inch lead branch pipe, with taps, &c. complete, will be 3*l*. 3*s*. per house. If there was a line of cast-iron service-pipes down each side of the street, the cost per house would not be increased, as the saving in branch pipes would pay for the otherwise increased outlay.

50. Also, what would it be if you had the distribution like back drainage at the back of the houses, and also how much would it save the tenant's cost on an average?—In this case I estimate the total cost of iron service and lead pipes, &c., at 27*s*. per house, and that this arrange-

ment would effect a saving of 38*s.* per house, of which the saving to the tenant would be 22*s.* I make this estimate upon the case above stated. I think the system of back supply would be found of great advantage in poor neighbourhoods, as, under the present plan, the poorer class can only afford to have the tap brought just through the front wall, so that the principal part of the water used has to be carried to the back premises. The system of back supply would do away with this inconvenience. Mr. Marten.

51. Will you give a return of the cost at which, supposing the whole service of the town had to be laid down afresh, you could lay it down for front supply; also the cost for back supply; showing the distinct cost of mains of service pipes, and the total cost to each tenant contrasted with the system of supply from the front of the street, and compared with the mode adopted in the metropolis?—Passing from the separate case above stated, and supposing the whole service of the town had to be laid down afresh, at present prices, it could be done on the system of front supply, at 63*s.* 6*d.* per house, of which the mains would cost 26*s.* per house, the service pipes 21*s.*, and the tenants' branches 16*s.* 6*d.* per house. On the system of back supply it could be done for 47*s.* per house; that is, supposing we had had powers to pass through the private property, both of those who did and those who did not take the supply, in the same manner as we have power to lay pipes in the streets. Of this sum the cost of mains would be 26*s.* per house, of services 14*s.*, and tenants' branches 7*s.* per house.

52. How much would the earthwork cost of that amount?—In the first case 5*s.* per house, and in the second, for back supply, 3*s.* 6*d.* per house. I am speaking of Wolverhampton.

53. How much of that cost would you save by combining the laying down of the return pipes at the same time as the supply pipes?—If both the supply pipes and the return pipes could be laid in the same trench and at the same time, there would be only one excavation to make instead of two, and the saving would therefore be equal to the cost of the earthwork per house for the supply pipes.

54. If you were to lay down a constant system of supply, with the substitution of soil-pans, &c., for cesspools, would you not expect that it would be necessary to have a man to look after the taps, the tenants' service pipes, &c.?—Yes. This department has hitherto been much neglected, and the tenants have often been put to considerable inconvenience and damage, first from want of a proper inspection of their supply-pipes, &c., so as to have them always kept up in good repair; and, secondly, by the attempts of ignorant and unqualified workmen to repair them. I think an inspection of these internal fittings, at stated intervals, by properly qualified workmen, would be a great advantage.

55. That would be economical to the tenants themselves, then?—Undoubtedly; they would be certain of having the work well done and well looked after.

56. From your knowledge of a London system of supply, and your practical experience of the change of the system of supply from an intermittent one, do you perceive any difficulties other than those you have stated in changing the system of supply in London from the intermittent to the constant supply?—I do not; as a rule the mains laid down for giving the intermittent supply will be found amply sufficient for giving

Mr. Marten. the constant supply, the submains and services always so. The idea that the pipes must be of sufficient capacity to allow all parties to draw from them at the same time is contrary to all experience, and in practice it will very rarely happen that so many as one-tenth of the population are drawing water at the same time. The pumping machinery and reservoir of the intermittent plant will also be sufficient for the constant supply, as less water is used under this system.

57. Then, keeping in view the system of supply in the metropolis, we understand that you are clearly of opinion that it is by no means necessary to the constant supply that the works should have been originally constructed for it?—I am of that opinion, and would only observe further, that before attempting to give the constant supply to any town which has long been accustomed to the other plan, I think it would be prudent that the whole of the works for so doing should be made perfect and complete. The town, on this being done, should be divided into districts, and the service-pipes and taps in each house put into a proper state for receiving the supply on the new plan, which should not be given in any district until these are proved satisfactory. Without these precautions, or some similar to them, in old towns, the constant supply would be deprived of a great portion of its efficiency. Little benefit can be derived from merely patching it on to the old system, but where it is determined to introduce the constant supply system the change should be thorough and complete. When, however, the necessary alterations are fairly planned out, previously to any change being made, and set about systematically, I do not think the slightest material difficulty can arise, and the increased domestic convenience afforded by this system, and the expansion it presents for sanitary improvement, will amply repay any temporary inconvenience in making the change.

Mr. John Roe examined.

Mr. Roe. 1. Were you not required by the Metropolitan Sanitary Commission in 1847 to gauge the run of water at given streets and sewers?—I was.

2. What was the result of your gaugings?—It is given in the following paragraph:—" It appears that in the second or third-rate class of streets, the run of water from the houses to the sewers is about 45 gallons per diem; but that in the streets of the first class of houses, all of which have water-closets, and all drain into the sewers, the daily run of water is, on the average, about 75 gallons per diem per house, except on the days on which the intermittent supplies are on, when the run increases in the third-rate streets from 45 gallons to about 78 gallons, and in the first-rate streets from 75 gallons to upwards of 100 gallons, during the day, affording an example of the waste incurred under that system. So far as the observations have proceeded, they are in corroboration of the opinion that the prospective estimate of a supply of 25 gallons per head of the population per diem, or 125 gallons per house, would effect all that at present appears necessary to keep a properly-devised system of house-drains and sewers of a town in salubrious action."

3. Have you since had the opportunity of observing your former gaugings and of carrying them further?—Yes, to some degree.

4. Was their correctness confirmed, or otherwise?—They were confirmed. Mr. Roe.

5. Will you state the result of your experiments as to the quantities of water?—In one long street the excess on water-days would average a depth during the year of 16 inches of rain over the area occupied by the buildings, gardens, and roads, or 22 inches over the area occupied by roads and buildings only. In another street the average would be 13 inches during the year in one case, and 21 inches in the other.

6. Your gaugings were, I believe, at the mouth of the sewer?—Yes, they were not gaugings of the butts, so I cannot say what was lost by permeation. All these experiments were tried on a gravelly soil, and much therefore would be lost in that way.

7. It has been stated that the loss on days when the water was not on was about one-eighth between the butts and the sewers?—That calculation is moderate enough; and when the water is on, the permeation of course must be greater.

8. Of course, in laying down new drainage works a great proportion of the expense is in earth-work?—The greater proportion of cost is in the material used, but the earth-work forms a considerable item in the total cost.

9. Might not water-pipes be laid down at the same time in general without double earth-work?—Yes.

10. Has it not been contemplated by the Works' Committee and by yourself that the superintendence of both should be under the care of one man on the spot?—Yes.

11. Did you not propose that the heads of sinks should be opened by only one key and one apparatus?—Yes.

12. Will you put in the form of apparatus you designed?—The drawings are in the office at Greek-street, whence a copy may be obtained, as they were ordered to be lithographed.

13. Then the business of one man, as contemplated, would be to cleanse the streets and courts by jet when it was required, and to be ready in case of any stoppage or disorder to set it right?—Yes.

14. Was not one mode of flushing by the removal of the cap of the house-drain and putting on the hose and cleansing everything by the discharge?—Yes.

15. Was it not contemplated that all the apparatus should be provided for under one rate?—Yes.

16. Do you see any reasonable probability of having such things carried out for a period of years, except by a common rate as a distributive charge?—No.

17. You are cognizant of the experiments illustrating the rapidity of the mode of cleansing by means of the jet?—Yes.

18. Do you think that either the water supply or house drainage can be carried out so economically separately as in combination?—I do not think they can.

19. Have you any doubt, as an engineer, that the like gain in efficiency and in economy which in drainage would be practically attained under the Metropolitan Sewers' Commission would be practicable also with regard to the water supply?—I have no doubt of it.

20. When you introduced flushing as a cheaper means of cleansing,

Mr. Roe. did you not expect to be obliged to have additional supplies of water for the purpose?—I did, and I applied to the engineer of one of the Water Companies to ascertain the prices at which they would furnish such additional supplies.

21. Did you not find that on days when there was an intermittent supply there was quite sufficient water?—Yes, without having occasion to purchase.

22. From your experience and knowledge, have you any doubt that your experience in this instance as to the available character of waste water for flushing is available universally by economizing the waste water on the days of supply?—I have no doubt of it.

23. Have you not carried out gaugings of the Fleet river at the request of the Commissioners?—In 1830 I began a series of gaugings in the Fleet sewer, and continued them at intervals to the time the Metropolitan Commissioners requested me to still continue them.

24. Did you observe any alteration on the days of water supply?—Yes, in a proportion very similar to what I have before stated.

25. What districts does the Fleet drain?—A large portion of St. Pancras; a portion of Islington; St. James Clerkenwell; and part of St. Andrew Holborn, and other districts below the point of observation.

26. What is the rate of discharge (in gallons) in the sewers in the street you mentioned in the New River Company's district, when the water was on and when there was no rain-fall?—The greatest flow observed was 160 gallons per minute.

27. What was the rate of run when the water is not on, and when there was no rain-fall?—Four gallons per minute.

28. In the River Fleet what was the rate of run at periods of time when there was no rain, and in days when the water was known to be on in the district?—The average rate of run during a month of dry weather, at the time when the flow was affected by the water-supply in the district, was 1,738 gallons per minute.

29. What is the rate of run at like periods of time in dry weather, and when the water is not on?—The water-supply appears to be on every day (except Sunday) in some portion or other of the district draining to the Fleet, parts of which are supplied by the Hampstead Water Works, and others by the New River. The rate of run, when not affected by the supply being on, was 756 gallons per minute.

30. What is the rate of run on days when there is rain? What is the rate of run on days when there is not rain?—The greatest quantity observed when rain fell was rather more than 800,000 gallons per minute. This was on August 1st, 1846; but this was not all that the Fleet was required to convey, had all reached it freely. But from its being too small at some distance above the point of observation, much water was backed up, causing the flooding of property to a great extent. The least rate of run observed during dry weather, at times when the flow was least affected (if at all) by house drainage, was 261 gallons per minute.

Mr. *James Stirrat*, Bleacher, Paisley, *examined.*

Mr. Stirrat.

1. Are you conversant with water-works in Scotland?—Perfectly.

2. Have you had occasion to notice those which derive their supplies from surface gathering grounds? More than any others.

3. At what places?—At Glasgow, Edinburgh, and Paisley, particularly. I was also seven weeks engaged by the Liverpool Corporation to give evidence in Committees of Parliament, and to examine the different streams on the Lancashire hills, whence they propose to derive a new supply of water. I find, as the result of my experience, that the purest and best soft water is *only* obtainable from lands lying on the primitive rock formations, such as green stone, granite, millstone-grit, &c. Rain-water from such districts, stored in large and *deep* reservoirs is as pure as it is practicable to obtain it, and the best in every respect for domestic and manufacturing purposes.

3*. Were not you the first individual who proposed this source of supplying Paisley with water?—I was the first to propose it in recent times, but the first individual who proposed it, so far as I know, was Lady Ross, the grandmother of the present Earl of Glasgow, who, about the year 1770, made an offer to the Magistrates and Council that, if they would make reservoirs and construct the necessary works, in the very manner which is now done, she would give the land gratis for the purpose; which offer they refused.

4. Of what degree of hardness is water obtained from such districts?—I am not accustomed to speak of water as to degrees of hardness, but am aware that as the quantity of mineral and saline matters held by water in solution is increased, so is the hardness. The water of the Clyde at Glasgow, for instance, contains on the average 15 grains per imperial gallon of such; whereas the new supply by gravitation from lands lying on the greenstone rock is so pure that less than two grains can be obtained only by the most minute chemical test. As simple a test of comparative hardness as I have used, is to boil two samples of water and test with a thermometer their comparative rates of cooling. The one which is purest invariably cools first.

5. How is Edinburgh supplied?—Partly from drainage off high grounds, and partly from the Crawley springs; the water there is harder than the new water at Glasgow or at Paisley, but softer than the water derived from the Clyde at Glasgow; but, in a dry summer, there is sometimes an inadequate supply. Companies have at various times, both at Edinburgh and Glasgow, been started to obtain fresh supplies from drainage alone, but they have been always thwarted by the old Companies, until the Gorbals Company in 1846, got a Bill for supplying the south side of the river Clyde, after great opposition from the old Company.

6. Having investigated the gathering grounds in Lancashire and in Scotland, is it not your general conclusion that the shorter the distance the water has to travel over the surface the less matter it has in suspension?—Certainly that is the case generally, although there are exceptions. Water flowing from high rocky districts is, as I have said before, very pure and soft, but as it generally comes on to more level grounds, where the more recent formations occur, such as lime chalk, iron, &c., it becomes more and more impregnated in its course

Mr. Stirrat. from springs and rain falling in the lower districts, and is of course less soft and pure. However, in other cases, particularly where a stream has its source in peat moss lands ; such water, although much discoloured at its source, becomes more and more pure, from exposure to the action of the atmosphere, and becomes quite clear.

7. From Mr. Thom's statements and other early documents, was it not estimated that only $\frac{1}{3}$ of any given fall of rain was available, and has not subsequent experience concluded it to be much more ?—Before investigations made by myself and others in my neighbourhood, Mr. Thom stated that it was altogether impracticable to supply Paisley in the way that is now done (that was in 1826), and again in 1835 he reported that as much as 18 inches *might* be available from the rain fall, and on this report the Company was formed ; but now, after an accurate measurement of the available quantity deliverable to the town, it is found to be about 36 inches annually on an average of three years,* and the consequence is that the reservoirs are of too small a capacity to contain the floods ; and although 50,000 of a population are supplied with as much as they choose to consume at all hours night and day, besides about 80 factories, comprising dye works, print works, &c., getting a supply varying from 1,000 to 150,000 gallons each daily, there is water wasted in the winter season, during floods, on an average to an extent that would give a supply to 20,000 more of a population.

We, the bleachers, printers, &c. whose works are on these streams, stipulated with the Company to have a supply to our works of *one-fourth* part of the whole water that might be found available from the drainage grounds intercepted by the water company, and that to be given off to us in a regular and uniform stream, and the quantity to be ascertained by a three years' measurement, and the average of these three years to be continued in all time coming, this was the reason of the measurements being made. I was appointed by the bleachers, &c., to see that it was done fairly by Mr. Thom, who was appointed by the Company. And we, (the bleachers, &c.) now find that during the four or five summer months, we have a regular stream from 20 to 30 times greater than before, and are protected from the winter floods which often did us much damage.

8. Then all subsequent experience goes to show this, that the quantity derivable from surface or gathering grounds is greater than was anticipated ?—Most unquestionably it is.

9. In this case is it mere surface water which is derived, or do you derive any of it through land drain pipes ?—All water is mere surface water in the first instance, and the only difference from that from drained land, that we have a greater *available* supply from any given fall of rain, because it comes more quickly off, and less evaporation takes place.

10. Then your opinion and experience is, that water does not lie on the surface where land is drained, it does not sink so far, and is more quickly delivered into a reservoir for distribution ?—Yes, that is precisely what I mean.

11. Supposing a given quantity of land were drained how much more

* This *available* quantity was derived from an average fall annually of 54 inches.

water would be likely to be obtained from it than it would yield if it were not drained?—This depends on the nature of the subsoil, but in every case drained land will produce more *available* water than land that is not drained. I may here mention that we find uniformly that in high districts the fall of rain is greater than in low districts. At Paisley, the drainage lands are on an average about 400 feet above the tide level, average fall of rain 56 inches a-year. At Greenock Shaw's Water-works, 16 miles west from this, average height of drainage land about 600 feet, average fall of rain about 65 inches, available 42 inches. In our district, on the above data, the available rain on 100 statute acres is more than sufficient to give 20 gallons a-day to each head of a population of 10,000 persons. The fall of rain, therefore, varies very much in different parts of the island. In Cumberland, where there is a large extent of high table land, about 2,500 feet above the sea, the quantity of rain is found to be 150 inches annually, and in London it is only about 22 to 27 inches. It is an interesting fact that, when Sir Christopher Wren was building St. Paul's Cathedral, he set a rain gauge in the church-yard, which indicated a fall of 22 inches. Since his day, until the last 10 years, almost all the rain gauges have been of an improper construction, and most of them now kept are still very defective; but it appears from recent observations that Sir Christopher Wren's rain gauge was a correct one. Mr. Stirrat.

12. It is stated that the rain gauge on the top of York Minster shows different results from that at the bottom of the building?—No doubt it will, and must do from a reason that it is easy to explain.

13. How much could be obtained from a fall of 20 inches near London?—It would depend on the soil on which it fell.

14. Have you observed the quality of the thorough drain water: we find upon getting analyses of surface waters compared with the thorough drain water, that there is generally less animal matter in it but that it is also generally much less hard than surface water?—We have not had occasion to observe any such difference.

15. Have you altered your mode of filtering water of late?—Yes; at Paisley, Greenock, &c., there is only one filter bed of *fine* sand. But at the New Works to supply Glasgow, we adopted, at the suggestion of Mr. Smith, of Deanstone, an entirely new mode, viz., three filters: the uppermost composed of rough stones from the size of a hen's egg and upwards, taken from the bed of the stream, where the water is allowed to rest as long as possible; and by the laws of gravitation these stones attract the light particles floating in the water, which are now seen to increase the size of these stones; it then passes into a second filter made of coarse sand or pebbles about the size of a common pea and smaller, which intercepts the gross particles; and lastly passes to a filtering bed of fine sand, and the consequence is, that the water is not only perfectly pure, but the fine filter which otherwise would have required washing once a week or so, works for six weeks or two months without the sand being removed to be washed and cleaned.

16. Do you get the water out as clear as spring water?—Yes, perfectly clear.

17. Is there any peat in those gathering grounds?—At Paisley, about 20 acres out of the 700; and at the Gorbals of Glasgow, somewhat less in proportion.

Mr. Stirrat.

18. Do you know any other gathering grounds where there is any tile-draining?—The Ayr and Kilmarnock.

19. Do they drain them?—Not the water Companies, but tile-draining is going on over the whole country more or less by the farmers.

20. Have you found any inconvenience from farmers draining or manuring land?—No; I have taken notes of the quantity of water coming off the high lands into the Paisley reservoir, and find that on an average of years, seven-tenths of the whole quantity is collected, or, in other words, flows off the high grounds in 27 days per annum. We have found no difference in the quality of the water from agricultural operations.

21. What is the extent of these reservoirs?—There are at Paisley in all three reservoirs, which contain 49 million cubic feet (49,000,000) having 790 acres of drainage ground.

In order to store up the flood-waters of a wet year so as to make up the deficiency of a dry one, and so as to lose no part of such floods, I find by the experience of the fall of rain in this district for the last 16 years, that storage room is necessary for two-thirds of the whole available quantity, that is for 24 inches from the whole drainage grounds; our reservoirs are, therefore, too small for the extent of drainage.

22. What is the greatest depth of your storage reservoirs?—At Paisley, 32 feet, where drawn off; and at Glasgow New Works, 51 feet: and we have the means of drawing off water at four different depths at both works.

23. How deep do you find plants grow?—I have found in this district that no aquatic plants grow where the water is 12 feet or more in depth, but that at a less depth they do grow and accumulate very fast. In a small reservoir at my own works, depth 8 feet, extent half an acre, I was much annoyed with such plants; but last year I got by advice a pair of swans, and they cleaned it completely in a few weeks, and it has been quite clean ever since, they would take no other food while these plants lasted.

24. One general evil in the storage of water is, that where the water is exposed to the sun, vegetation grows and animal life ensues. It has been suggested to roof the reservoir where that can be managed, and the question is whether a floating roof cannot be constructed?—We have had under consideration the roofing of the filters and distributing tank, which are liable to the objection you mention, and which can be easily done at a small cost; but as to covering or roofing the storage reservoirs that is altogether unnecessary, as nothing of the kind affects us in so deep water.

25. We find at present we can cover a reservoir at about 1,000*l.* an acre.—It would be an immense work that would require a distributing-tank and filters to occupy even two acres of land—this would be sufficient for London.

26. Would not that have the effect not only of preventing the water spoiling, but of preventing evaporation?—It is a great mistake to imagine that evaporation takes place to any extent, even in the height of summer, from the surface of a reservoir where the water is of any considerable depth. The deposit of dew, I think, counterbalances it. I have one pond 10 feet deep, on which I made the experiment, and found in the heat of summer that in two months it did not go down one-

sixteenth part of an inch; and there might have been a small escape to account for even that diminution. Mr. Stirrat.

27. Do you line the sides of the reservoirs?—No; that is not at all necessary. We only line the inside of artificial embankments with rough broken stones.

28. It is the result of much experience in England, where water is derived from rock of the primitive formation, that, after coming through a channel of clay, it is of 10 or 12 degrees of hardness. It has been found in the instance of the Surrey canal that the hardness of the water rises in a curve?—I have found almost uniformly, that where rivers have a long *slow* run, it becomes harder the farther from its source. Thousands of contributing springs will no doubt produce this effect, by bringing mineral and saline matter into the main stream.

29. On the whole it is in accordance with the experience of the General Board of Health, who have received and have investigated some two or three hundred specimens of waters, that, on an average, well and spring waters are of 20 degrees of hardness; river waters, 13; and surface drainage water, about 5 degrees of hardness?—I have no doubt that that is an accurate calculation as a general average.

30. Have you been among or known populations, who, after having been used to soft water for drinking have had to come to the use of hard, or the converse?—At Paisley, they used to have water from spring-wells for drinking, but these springs contained iron, lime, and magnesia, although very pure to look at; and the population never complained of their use for anything but washing, for which they were not suited.

About 30 years ago, water began to be carted along the streets and sold to the people. This water was pumped up from the river and filtered, and was much softer than the springs, and did very well for washing and infusing tea, &c.; but since the introduction of soft surface water by the Company, the wells are not used for any purpose whatever, being totally neglected; and for drinking, the water of the Company is universally preferred, and relished most of any. I may here mention that the quantity now consumed for domestic use is so great, that had the people used the same quantity at the price charged from the barrels above-mentioned; it would have cost upwards of 100,000*l.* annually, and for which they now pay under 3,000*l.* annually.

31. Do you know that well-water derives its attractiveness from its coolness and freshness?—No doubt it does; averaging in summer from 45 to 55 degrees of heat; but our water from the main pipes is also quite as cool and clear, being under constant pressure in the pipes, and no cisterns in the houses where it would become heated and be thereby rendered unpleasant to drink.

32. But it has been objected to, and particularly by Mr. Thom, that water-pipes have been laid too near the surface?—Mr. Thom is quite correct in this remark; but, at Paisley and the Glasgow New Works, the pipes are laid 3 feet from the surface, and the water is found to be at all seasons quite cool enough.

In London, Manchester, &c., where water is taken into cisterns, in warm weather it uniformly becomes tepid and unpleasant to drink. In Liverpool, the water is very hard. I could wash at home without soap as well as at Liverpool with soap. I have stated that we are supplied at Paisley on the constant service principle, and the pressure (120 feet)

Dr. Stirrat. has never been off since 1838, when the supply began—except for part of a street, when occasionally the joint of a pipe was leaky and required repair, which operation is very easily and quickly done.

As to the effect on health in drinking and cooking with hard water, as compared with soft or rain water, it is a fact worthy of attention, that in Paisley, before soft water was introduced, cases of stone in the bladder were very frequent; and the late Dr. Stewart, an old and experienced practitioner, informed me that he had at one time known as many as a hundred cases in a year where an operation was necessary to extract stone from the bladder, besides many minor cases, where small stones were passed without operation; these cases somewhat diminished in number on the introduction of river water being sold from barrels; but that on the supply by the Water Company of pure soft water, such cases diminished year after year, and that for the last seven years there has not been a single case known to any of the faculty, unless where it had been generated in some other part of the country, and imported into the town. I find also, from inquiries made, that in Aberdeen, where the water flows wholly from granite, that the disease is unknown; the same is the result in the high parts of Derbyshire in England. On the other hand, in the county of Norfolk, where spring-water is used highly impregnated with mineral and saline substances, this disease exists in almost every family, more or less. I mentioned these facts to James Paton, M.D., of Paisley, and although he had not taken notice of the circumstance previously, he says it is quite correct; and that also diseases of the kidneys and liver, generated from the same cause, have wholly disappeared in Paisley.

33. From Bolton, we are informed that, since the introduction of soft water, the cases have diminished enormously. On the other hand it is stated that this result is rather owing to a diminution in the quantity of beer and other such beverages that are drunk?—The late Dr. Stewart, of Paisley, did not take that view of the subject; but he told me that for upwards of 20 years previous to the soft water supply to the town, he had not allowed the use of hard water in *his* family, they using the rain-water collected into a tank from the house-roof. The same effects may be observed in kettles and boilers in the quantity of fur where hard water is used.

34. During periods of epidemic disease, have you observed the different results of hard and soft water?—In Paisley, in 1832, every district of the town was affected with cholera, at which time there was no supply of water; but in 1848–49, in a high district, (Charleston,) with about 4,000 inhabitants, having no supply of water but spring-wells, the number of deaths were between 200 and 300; and in all the rest of the town, where the water supply was taken, the whole number of cases, I think, were under 50, and the deaths under 20.

In the Gorbals side of the city of Glasgow at the same time, the attacks of cholera were trifling, and the deaths very few; but on the north side of the Clyde, where the Clyde water is used, the cases were 4 to 500, about the half of which died. In 1832, the south side suffered most severely, and at that time they also used Clyde water. I cannot say positively, that all this was in consequence of using soft water; but such facts are worth attention.

35. Then, on the whole, the preponderance of experience goes to

support the greater salubrity of soft water over hard?—There is no doubt of that. Mr. Stirrat.

36. What is your experience as to the effect of soft water in cooking, tea-making, and washing?—Since we have used soft water, there is no comparison as to its value. For infusing tea, the flavour is good with a much less quantity; and in cooking, we of course get rid of all those deleterious substances, which, in an imperceptible manner, generate diseases; and as to washing and bleaching, any industrious housewife can tell the advantage. I should say, from experience as a bleacher, that if I were compelled to use the London or the Liverpool waters in my trade, that for every 1,000 lbs. of soap I use, I should have to use at least 2,000 lbs., and, after all, the same cleansing effect would not be gained.

37. What is your opinion, from your experience, as to the constant service supply, and the intermittent supply. Viewing it in relation to the modes in which the towns in England and Scotland are at this time supplied with water, and as to the expense, advantages, and disadvantages of the one mode as compared with the other?—I am most decidedly in favour of the constant supply system, whether I look to the interest of the Water Company or to the consumer.

There is less waste of water, the consumer never taking more than he wants at the time. The pipes of the Company are not corroded, the action of the atmosphere on the pipes in a damp state when empty being the cause of corrosion. Pipes under constant pressure will last three times longer than on the intermittent supply principle. The population have the use of the water at all hours, night and day. They have it at all times clear and cool.

In cases of fire it is almost impossible to calculate its value.

In Paisley we have fire-plugs on the mains, and also at Glasgow New Works; in the latter place there is a pressure of 220 feet, and by attaching a hose to a fire-plug, which is the work of only a few minutes, any fire is immediately extinguished. It is scarcely possible to burn a house, the flow of water is so great and continuous, without any manual labour, that an ordinary floor of a house can be filled with water in 10 minutes. I do not mean to say that fire-engines should be dispensed with, as it is evident circumstances will occur where they may be of much use; but I say that in nine cases out of ten, if fire-plugs are placed at convenient distances on the mains, fire-engines will very seldom be needed. The New Glasgow Water-Works are the most complete and perfect in the kingdom, being self-acting throughout, by the self-acting sluices, invented by James Macinlay, who constructed the Shaw's Water Works at Greenock. Thus, supposing a great fire to take place in Glasgow (south side of Clyde), and four or five times the quantity of water were required that is usually given off, the moment such extra quantity is drawn off from the main pipe, these sluices act from the city on the reservoir, (five miles distant) and the same quantity as is drawn off the main pipe in the city, is discharged from the reservoir into the distributing-tank, and this discharge will continue for any length of time required, without the aid of any one, or any manual labour whatever.

This apparatus, however, would require to be seen and examined on the spot to be duly appreciated. The water here flows 40 feet (out of

Mr. Stirrat. the hose) above the highest house in the district, and when water is thrown on a house with *great force*, it is separated into millions of particles, and an immense amount of steam produced, which soon extinguishes a fire.

38. If a fire takes place in London, the average time before adequate aid is procured is above 30 minutes?—The time must vary according to circumstances; but with the fire-plugs and hose attached, the time generally will only be about one-fourth of that by fire-engines.

39. Have you not got into the habit of washing the streets by jet?—Not yet. I wished, as a member of the Town Council, that it should acquire the water-works to be under the control of the Corporation, in order to have that and other sanitary measures adopted; but so far we have not agreed on the terms. For many reasons, I am decidedly of opinion that Corporations alone should possess the right of supplying a population with water, and not a trading Company.

In the Gorbals of Glasgow, water is given gratis to all persons on the pauper-roll, and also to public bath and washing houses, if such should ever be erected.

40. What are your prices of a constant supply of water to small tenements?—In Paisley, there is a population of upwards of 40,000 supplied with water, the total population being 50,000, yet the whole rental of the burgh is only 50,000*l.*, including factories, &c.; the lowest charge there is 5*s.*: but, in the Gorbals of Glasgow, the charge is only 1*s.* per pound on all rentals; of course an apartment, rent 2*l.*, is only 2*s.* I may here state, that a charge on rental is not a fair data to rule by as to water-rates, that is, as to the price of any given quantity supplied. A house in Paisley may be had for 100*l.* a-year, that at Charing Cross in London would be rented at 300*l.*, and the *quantity* of water consumed in both houses be about the same.

41. Do you find convenience and improvement as a landlord from the more plentiful distribution of water?—I certainly do. The houses are much cleaner and in better condition in all respects. I have the charge of tenements, my own, and in trust for deceased friends, containing about 250 tenants, and I cannot let a house to any good tenant, even of the lowest labouring class, if water is not laid on in it. The poorest person will not take a house without water-pipes in it, if he can procure one with; and they uniformly prefer a house with the water INSIDE.

42. What is the quantity of water consumed by each person in your town?—The quantity given off now from the reservoir amounts to 45 gallons daily to each head of the population, but fully 25 gallons of this is used for manufacturing purposes, leaving nearly 20 gallons a-day for private use. I am aware that this is considered a large quantity, as compared with some other towns, but it is easily accounted for.

As an instance, in London the clothes are given out to the country to wash, but in Paisley nine-tenths of the population are of the working class, who wash all their clothes in their own kitchens, and having no water-closets, the quantity of water used where they have it so conveniently is much larger in washing their pots, than if they had a water-closet to resort to.

43. In Scotland, are the towns supplied generally on the constant

service principle, or by an intermittent supply?—By the constant service, in almost every instance. Mr. Stirrat.

44. Can you enumerate the places supplied by constant service?—Glasgow New Works, Paisley, Aberdeen, Dundee, Ayr, Kilmarnock, Pollockshaws, Govan, Troon, Ardrossan, Perth, Montrose, Greenock, Crossmyloof, Strathbungo, and many others; and Bills are now in Parliament to supply other towns on the same principle, viz., Nitshill, Hurlet, Barrhead, Neilston, Rutherglen, Dumfries, &c., &c.

45. What is the size of the main at Paisley, and the New Works at Glasgow?—At Paisley, 19 inches, with a pressure of 120 feet; and at Glasgow, 2 feet, with a pressure of 220 feet.

46. In London, it is estimated that the expense of washing is 1*s*. a-head per week, making the annual expense of washing in the metropolis not less than 5,000,000*l*. a-year; how much do you think a supply of soft water would save in soap in a year?—I should say, from my experience as a bleacher, that if we had to use water like yours in London, we should have to use at least twice the quantity of soap that we now consume.

47. What is the size of the service-pipes used by you?—In Paisley, half and three-quarter inch; in Glasgow, half-inch, in almost every case of domestic supply; and in Stirling, only quarter-inch lead pipes; the pressure in the latter place being 450 feet, these small pipes are found to be quite large enough.

48. Have you ever used clay pipes?—Such pipes were tried at Greenock, but were not found to answer; they gave way at the joints, and the jointing of them was found expensive and unsatisfactory.

49. Are there any other pipes than lead and iron that may be used, combining cheapness, and adding purity to the water?—Iron and lead are the only pipes that we have found to answer. Since I came to London at this time, I have been making inquiries as to glass pipes, and am offered, by Mr. Lochhead, the seat 1½*d*. per lb., to stand a pressure of 400 feet, and to be jointed with melted glass, by means of the blow-pipe, with solid glass. I have ordered a few, to make the experiment, but cannot say how it may do until a trial is made. Clay pipes were used in ancient times to supply water; as an instance, King Hezekiah (see 2nd Book of Kings, chap. 20, verse 20, and 2nd Book of Chronicles, chap. 32, verse 30,) brought in water from Jerusalem; his pool and conduit are still to be seen; the conduit is 3 feet square inside, built of freestone, strongly cemented; the stone 15 inches thick, evidently intended to sustain a considerable pressure of water, and I have seen pipes of clay taken by a friend from a house in the ruins of the ancient city, of one-inch bore, and about seven inches in diameter, proving evidently to my mind that ancient Jerusalem was supplied with water on the principle of gravitation. The pools, or reservoirs, are also at this day in tolerably good order, one of them still filled with water. The other, broken down in the centre, no doubt by some besieging enemy, to cut off the supply to the city.

50. What is the proportionate amount of storage necessary?—We find that in order to store up all the floods, so that no water may be lost, that we must have storage-room provided for two-thirds of the available quantity, that is, at Paisley, for 24 inches in depth from the extent of drainage. This storage is sufficient to store up the surplus

Mr. Stirrat. of wet years to make up for the deficiency of dry years on an average of 16 years' experience of the rain-fall, &c.

51. Then, on the whole, you find, that the constant supply at Paisley, and other places, constitute an immense and efficient preservation against fire?—No doubt of it. Many fires occur, but when the alarm is given, they are generally quite out in half an hour afterwards.

52. Have you heard at Paisley of pipes freezing?—The main-pipes never freeze, but sometimes the service-pipes do, where they are improperly placed.

53. What is the softest water you know to be supplied to any town?—The towns which have the softest water supplied are Paisley, Glasgow (New Works), Aberdeen, Dundee, Montrose, Ayr, Greenock, Kilmarnock, Troon, Ardrossan, &c. There is not much difference in any of these. There is no chalk nor lime in any of these waters, being all collected from hills of the primitive formations.

54. Have you found any inconvenience from the constant pressure in repairing pipes or mains?—Not at all; we have sometimes had occasion to deprive a street of water for a few hours, to repair a joint of a pipe, but that occurs very seldom indeed; not a dozen of places require such repair in twelve months in our population of 50,000.

55. In London it is said that soft water causes corrosion in pipes, and is liable to poison the population?—There is no such effect; such an idea is downright nonsense; corrosion in pipes takes place only under the intermittent supply, by the action of the atmosphere on the pipe in a damp state; and, as I have said before, an iron pipe constantly charged will not corrode at all, whether the water be hard or soft, and will last at least three times as long as a pipe into which the air is admitted.

56. What kind of pipes do you prefer—earthenware?—I should certainly say glass, if the cost and jointing could be properly managed, which, I am of opinion, will soon be done. Earthenware is unexceptionable, if it can be had to stand the pressure, and at a cost as cheap as iron. Lead pipes do give a taste unpleasant to the water, if not constantly being drawn off.

57. In London, not only the common air gets into the pipes, but the real gas gets in also?—No doubt of it. This must be the case, when the pipes are emptied of water; but on the constant pressure, nothing of the kind can by any possibility occur.

58. It has been alleged that if the supply of water were constant, that it would require an interference on the part of Water Companies that would be objectionable and unpleasant to consumers?—Experience shows that where water has been taken INSIDE of houses that it is well taken care of; whereas wells supplied by the Company at the backs of houses, open as they often are to a dozen of tenants, no care at all is taken of, on the principle that what's every body's business is nobody's; but when inside of a house every one takes care of his own, and there is no inducement to use more water than what is absolutely necessary. This almost entirely saves interference on the part of the Company.

59. Can you give the prime cost of bringing in water to the towns you mention, the population of the towns, and the annual expense of conducting the works, &c.?—Yes: at Paisley the cost

was 61,000*l.* Sixty-one thousand pounds, and I could have done it for 35,000*l.*, with the assistance of James Mackinlay, whom I have mentioned; but a very great extra expense was incurred from Mr. Thom's mistakes; but he being what was styled an EMINENT ENGINEER, his advice was followed at a great loss to the Company. Notwithstanding these drawbacks, we pay a 5 per cent. dividend annually, and for 10,000*l.* we could double the supply of water. Mr. Stirrat.

60. At the Gorbals Water Works, in Glasgow, can you state what the entire cost amounts to?—I can. The estimate by Mr. Gale, Civil Engineer, was 97,000*l.* and to complete the works 110,000*l.* were expended, but considerable additions have been made to the works involving fully 10,000*l.* of extra expense; so that the first estimate is beyond the sum that would have been required to finish the works as at first contemplated. This 110,000*l.* gives an ample supply to a population of 150,000, and a Bill is now in Parliament to increase these works; whereby, by an outlay of other 25,000*l.*, an ample supply can be obtained to a population of 250,000 allowing 20 gallons daily to each head of the population.

61. Then, you bring the cost of the main apparatus down to how much per head of the population?—The Gorbals Water Works would be at the outset about 16*s.* per head. The New Works contemplated will reduce it to about 10*s.* per head of an outlay, and to include the service-pipes to every family *inside* of the house, it will not exceed (12*s.*) twelve shillings per head.

62. What is the effect of the constant supply as to the quantity of water used?—There is less used unquestionably under the constant supply than by the intermittent supply, and, as I before said, it is the best system for the Companies, and also for consumers, in every respect.

63. What is the annual cost of management at Paisley and Glasgow New Works?—At Paisley under 600*l.*, and at Glasgow under 900*l.*, including all charges, cleaning filters, mending fences, &c.; and the annual expense will not increase with the extension of the works.

64. Then are you of opinion that a Water Company should not only lay the main pipes, but also the service pipes to each house?—I am most decidedly of that opinion, both for convenience to the consumers of water, and for economy and efficiency. The want of this power is the only deficiency in the Scotch Water Companies to which I have referred.

COPY of a LETTER from MR. GALE.

SIR, *Glasgow, 22nd April* 1850.

In reply to your letter ($\frac{1043}{50}$), dated 16th instant, regarding the Inquiries which the General Board of Health are now instituting on the subject of a supply of water to towns, I now beg to offer the following remarks:—And, 1st. As to the source to be recommended, for giving a pure and abundant supply to a town; I would, generally, give a decided preference to the mode of collecting the water in reservoirs, from streams and surface drainage, where this is practicable, and can be accomplished at a reasonable outlay. Mr. Gale.

The plan which I usually adopt, is to fix upon a stream or streams,

Mr. Gale. on sufficiently elevated grounds, so as to admit of the water being introduced by gravitation.

In determining the position for the reservoirs, I keep in view the propriety of arranging them, so as to admit of extension from time to time, as the demand might increase, by the construction of additional reservoirs, on ground still more elevated, either in the same or the adjoining vallies, whereby the additional supply could be drawn into the lower reservoirs, and from thence into the filters.

This is a matter of essential importance where towns are rapidly increasing in population.

Water thus collected is generally found to be almost entirely free from matter held in solution, and that held in suspension is allowed to settle down to a great extent in the reservoirs and is drawn off to the filter beds in a comparatively pure state. It is also generally found to be remarkably soft, superior as a beverage, when properly filtered, to hard water, well adapted for brewing, making tea, washing, and culinary operations; or in other words, it is greatly to be preferred to hard water, for all domestic and manufacturing purposes whatever. The hardness of water thus collected I have found ranges from about 4 to 7 degrees, depending to some extent on the quantity and quality of the spring water, which must of necessity mingle with the soft when collected in the reservoirs.

There is also a better opportunity by this mode of getting water unpolluted by public works, and the refuse and sewerage of towns, which flows directly or derivatively into most large rivers, and which may be preserved from contamination by Legislative enactment.

Further, it is almost invariably found, that hard water is impregnated, to a greater or less extent, with carbonate of lime, and other deleterious substances held in solution, the constant use of which has a tendency to produce gravel and stone in the human system. In proof of which it may be stated that the inhabitants of the town of Paisley were much afflicted with these diseases previous to the introduction of pure soft water into that town, whereas now they have almost entirely disappeared; and again, the inhabitants of the town of Kilmarnock are, up to this moment, similarly afflicted, arising from the almost exclusive use of hard spring water.

In this latter case I anticipate a remedy in the course of a few months, by the introduction of a plentiful supply of soft, pure filtered water.

Again, during the late attack of cholera, both in Paisley and Gorbals, the cases were comparatively rare, with the exception of that portion of Paisley beyond the range of the Water Company's pipes, where the cases were numerous; and in the same town, in the first attack of that disease, before the water was introduced, it was very severely felt. The town at that time, was supplied partly from springs, partly from roof water collected in tanks, and partly by carrying it from the River Cart, and doling it out to the inhabitants in pitcher fulls, in the same way as is done in the town of Dumfries at the present time.

The south side of the city of Glasgow, including the town of Pollokshaws, with other villages along the line of mains, comprehending a population of about 75,000, is supplied from a stream, draining 2,750 acres, distant from Glasgow about 7 or 8 miles, which stream,

by the formation of another reservoir, immediately above those already executed, (a Bill for which is now before Parliament) will then yield an abundant supply of water of the finest description to a population of about 250,000. Mr. Gale.

The town of Paisley, containing about 60,000 inhabitants is amply supplied from a drainage of about 700 acres, besides giving compensation to the mills.

Stirling with a population of 10,000 is supplied from a drainage of about 150 acres; the contributing ground in this case being chiefly whinstone and hilly pasture; filtration was found to be unnecessary on account of the purity of the water collected in the reservoirs. The contributing grounds to Gorbals and Paisley were pasture and arable land, and in both cases the water is filtered.

In the towns above enumerated, the water is giving entire satisfaction to the inhabitants, and the Towns of Kilmarnock, Stranraer, Dumfries, and Maybole, are following out the same system of supply, which I have no doubt will give equal satisfaction when introduced,

There are many objections to the system of pumping water from large rivers, for the supply of towns. In the first place, it is found that they are generally liable to become polluted by public works and from the drainage of towns and villages, an evil which is gradually increasing; this is felt mostly during long droughts, when the waters are in a low condition; as an example, the Glasgow Water Company draw their supply from the River Clyde, about two miles above the city, above which point there have been numerous public works and populous towns and villages sprung up on the river and its tributaries. This growing evil compelled the Company to apply for power to have it remedied, by drawing their supply from a source, upwards of 30 miles distant from the city; the power was granted, but the works have not yet been carried into execution.

Further, in drawing from rivers the water would necessarily be drawn at times, when it was in a turbid state, tending more readily to choke up the filters; and again, when water is abstracted from a river, compensation in money would have to be paid to parties interested, in many cases, as no compensation in water could possibly be given. Whereas, by storing up the surface-water, as has been proposed, in reservoirs on elevated grounds, compensation in water may be given out regularly during the whole year, generally to the extent of one-fourth of the whole available fall of rain; whereby the mills and public works are infinitely better supplied than they are, when obliged to take the water when it comes, at one time having a great deal too much, and at another a great deal too little.

Another advantage a gravitation scheme has over a pumping scheme is, the comparatively small annual expense required for the former, where the works are properly constructed. In the case of the Gorbals gravitation Water Works, one superintendent, with the occasional assistance of two or three labourers, when cleansing the filters, is found to be quite adequate to send a constant supply of pure water into the town; and were the population trebled, the additional expense in cleaning the filter beds would be but trifling.

As to the mode of supply from wells or deep springs, I am of opinion that it should never be resorted to, if it be possible to get a supply of

Mr. Gale. pure soft water, even although the original cost of constructing the latter should exceed that of the former to a considerable extent, and that for the reasons already stated, with regard to its quality and the constant expense of pumping. Further, casualties are by no means of rare occurrence, which affect to a great extent both the quantity and quality of the water of springs, and, therefore, I could not recommend that mode of supplying a town with pure wholesome water.

As to the adoption of a constant supply in preference to an intermittent one I think there can be but one opinion, and I feel satisfied that no one having had the experience of the former would ever think of falling back on the latter. The reasons are obvions. First, it is less expensive in the annual outlay, fewer hands being required. Second, the water is less disturbed in the pipes, and is introduced into the houses in a fresher state than if allowed to stagnate in the pipes and cisterns. Third, there is no necessity for the tenements being supplied with tanks or cisterns. And, lastly, in the event of fires, the water being constantly at hand, the plugs may be opened without delay. And where the source of supply is sufficiently elevated, the aid of fire-engines may be altogether dispensed with, as in the case of Gorbals where there is a head pressure of 225 feet; Stirling with a pressure of 450 feet, and Kilmarnock with a head of 270 feet.

The pipes in all cases are constantly charged, and by the adoption of the improved fire-plug, and connecting stand pipe four hose may be made to play from each fire-plug with better effect than with as many engines.

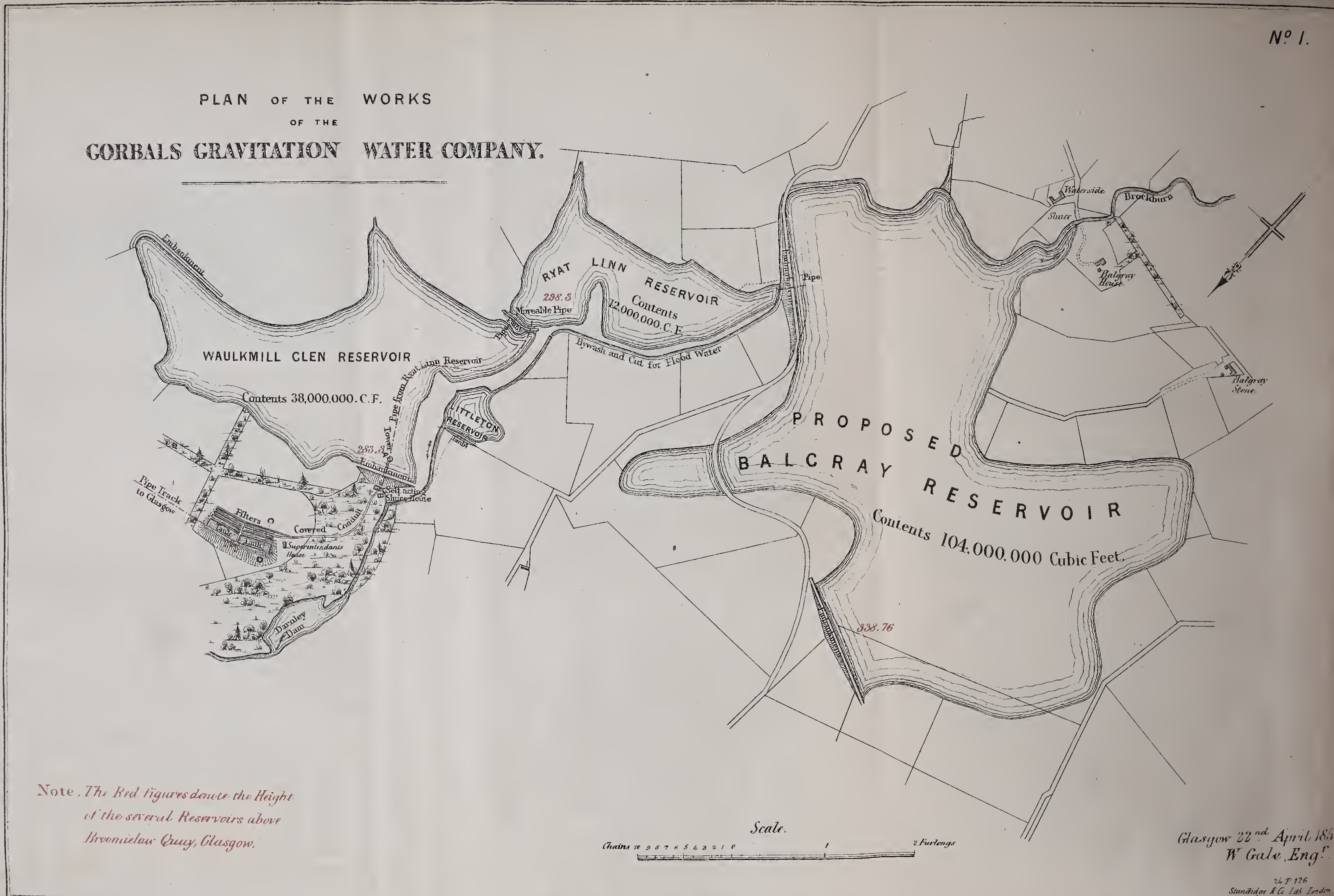
Fires have occurred in Gorbals where they have been got under and extinguished before the arrival of the engines and their attendant butts. This is a matter of great importance in all large towns where so much property is annually destroyed by the ravages of fire.

In concluding this part of my remarks I would merely state, that if possible, where any new Water-works are to be established the system of constant service should be adopted; and in cases where the intermittent system is already in existence, that the advantages of a change to constant service would more than counterbalance the expense of making the necessary alterations.

As to "the average daily domestic consumption, as distinguished from the quantities used in manufactories, or by other large consumers, and that used at standpipes, and in watering roads and streets, and other public purposes," there is some difficulty in arriving at definite conclusions in detail, on account of the want of proper meters for the public works, this defect I expect soon to overcome, when I shall institute some experiments so as to get proper data upon which to proceed. The results, when obtained, I shall be glad to transmit to the Metropolitan Sanitary Commission.

In the meantime, I may observe, that from observations made on the total consumption in Gorbals, for all purposes, it averages about 32 gallons to each individual, daily; and that for a town such as Glasgow nothing less should be calculated on where so many of the houses are fitted up with baths and water-closets, and where manufactories and other public works are so numerous.

In towns such as Kilmarnock, Stirling, &c., where the luxury of a bath is rarely met with, except in the higher class of houses, and


No. 1.
PLAN OF THE WORKS OF THE
GORBALS GRAVITATION WATER COMPANY.
WAULKMILL GLEN RESERVOIR
Contents 38,000,000. C.F.
Embankment
RYAT LINN RESERVOIR
Contents 12,000,000. C.F.
298.3
Moveable Pipe
Bywash and Cut for Flood Water
Pipe from Ryat Linn Reservoir
LITTLETON RESERVOIR
283.3
Tower
Self acting Sluice House
Pipe Track to Glasgow
Filters
Covered Conduit
Superintendants House
Darnley Dam
Pipe
PROPOSED
BALGRAY RESERVOIR
Contents 104,000,000 Cubic Feet.
338.76
Waterside
Sluice
Brockburn
Balgray House
Balgray Stone
Note. The Red figures denote the Height of the several Reservoirs above Broomielaw Quay, Glasgow.
Scale.
Chains 10 9 8 7 6 5 4 3 2 1 0 1 2 Furlongs
Glasgow 22nd April 1850.
W. Gale, Engr.
Standidge & Co. Lith. London

where public works are not so numerous in proportion, 25 gallons daily, and for small towns 20 gallons should suffice. Mr. Gale.

I am aware that in some small towns the inhabitants would not use more than one-half that quantity; but in a sanitary point of view, I am of opinion that nothing less than 20 gallons daily to each individual should be calculated upon for all purposes.

I beg further to annex analysis of the water supplied by the Gorbals Gravitation Water Company:—

	Grs. in imp. gall.
Organic matter	1·150
Carbonate of lime	3·610
Sulphate of lime	·870
Common salt	·881
Sulphates of potash and soda	·299
Magnesia	·120
Oxide of iron	·070
Silica	·150
Total quantity of foreign matter	7·150
Specific gravity	1·000·159
Degrees of hardness according to Dr. Clark's scale and process	4·25°

The above analysis was made on the 27th June 1845 from specimens taken from the running stream, and no analysis has been made since the works have been completed; but I believe that, from the subsidence in the reservoirs and the filtration which the water afterwards undergoes, that the water will not only have been deprived of all organic matter held in suspension, but also that the amount of other foreign matters held in solution will have been to some extent reduced, rendering it nearly equal to rain water, seeing that the specimens were taken in dry summer weather.

As to the evidence of Mr. Martin, of Wolverhampton, and the statement of Mr. Coulthart, of Ashton, I entirely coincide with them in the advantages to be derived from a change from intermittent to constant supply.

I do not, however, think that this change should require the laying down of larger mains as stated by Mr. Coulthart.

I am a little surprised that so little water is used for domestic purposes both at Ashton and Wolverhampton, but I have no doubt that the statements made regarding the supply of these towns are quite correct.

There is a difference of opinion regarding the propriety of reticulating the street pipes throughout a town, but this is a point which is probably unnecessary to examine in these remarks.

I beg to send annexed to these remarks a few tracings explanatory of portions of some of the works in which I have been engaged, and which may probably be of some use in drawing up the Report of the Metropolitan Sanitary Commission.

Drawing No. 1 exhibits a plan of the reservoirs, and other works connected therewith, belonging to the Gorbals Gravitation Water Company, which have been in operation for upwards of two years; also of

Mr. Gale. the proposed reservoir immediately above those already constructed, to which reference has previously been made; which reservoir, including those already constructed will contain 962,500,000 gallons. The lower reservoir is filled up from the upper ones so soon as the water has been allowed to settle; thus keeping the water in that reservoir which supplies the filters in a comparatively pure state.

Drawing No. 2 exhibits the lower reservoir in connection with the self-acting sluices, filters, and pure water basins. By means of the self-acting apparatus which has been adopted, the pure water basins are kept at the same level, whether the draft at the town be great or small, by first operating on the conduit leading to the filters, and then upon the valve on the pipe leading through the embankment to the lower reservoir—thus making the whole works self-acting, without the intervention of manual labour.

Drawing No. 3 shows, on an enlarged scale a plan of the filter beds and pure water basins. It will be seen that there are three filtering beds and basin in duplicate, either set of which can be worked while the others are being cleansed: the water, upon leaving the conduit, passes through the upper filter, rises up in the hollow-wall, separating the centre from the upper filter, falls on to the second filtering bed, passes through the filtering material of sand and gravel, rises in the second hollow wall, thence through the material of the third filter, composed of sand, again rises in the hollow wall, separating the lower filter from the pure water basin, and at length into said basin, by which means, the whole water undergoes a triple filtration. The water is conveyed from the pure water basin into the town by a 2-feet main, and distributed by constant service in the usual way.

Drawing No. 4 exhibits the various heights of the reservoirs and pure water basins above the Broomielaw Quays at Glasgow.

Drawing No. 5 shows a section of a similar arrangement to the Gorbals Water-works now executed for the town of Kilmarnock, but upon a much cheaper and simpler plan; the whole of which, as in the Gorbals Works, is self-acting throughout.

Drawing No. 6 shows how, in a small town such as Stranraer, where the water is collected in the reservoir in a comparatively pure state, may be sent into the town without filtration by means of a moveable pipe and float, surrounded with fine wire gauge screens which retains matter held in suspension, and from the simplicity of the arrangement, can be taken out and cleansed when found necessary.

One of the great objects I have invariably found in supplying small towns is an economical mode of constructing the works, otherwise the projects would, in many cases, have been abandoned.

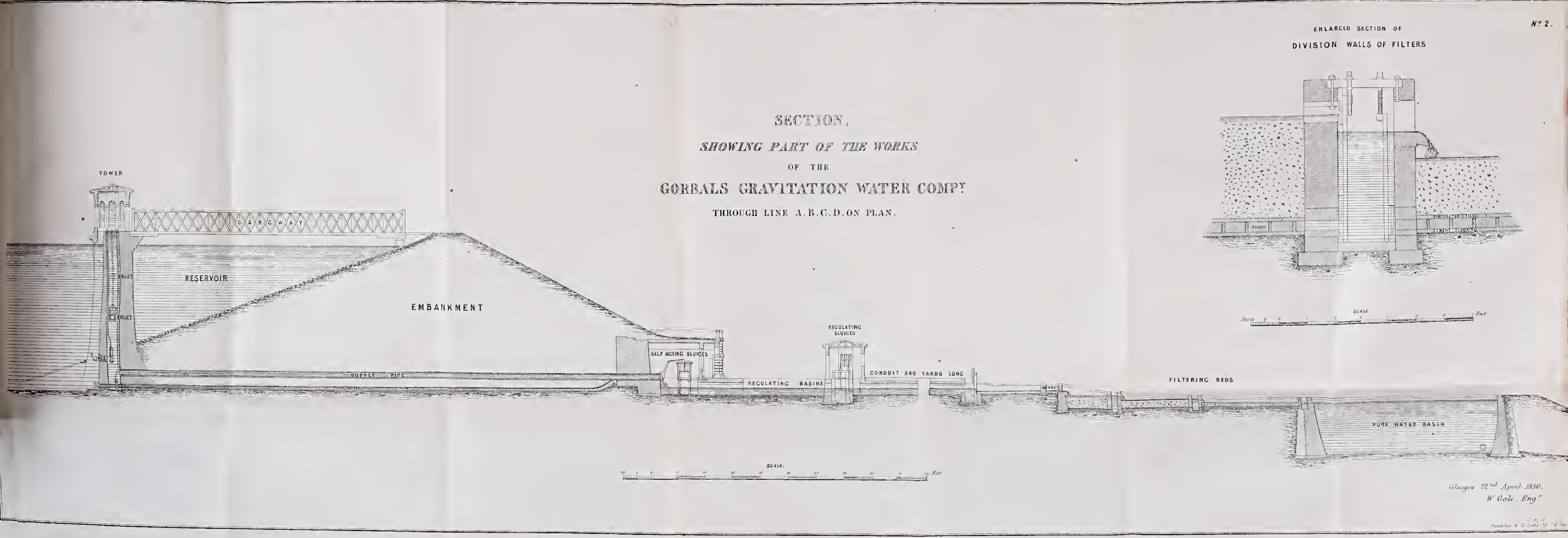
In concluding these remarks, I would beg to state that I shall be happy, if required, to furnish any additional information in my power, as well as give such facts bearing upon the subject which may be elicited from time to time in the prosecution of, or experimenting upon, a branch of engineering so deeply affecting the well-being of society wherever congregated in masses.

I have the honour to be, Sir,

Your most obedient Servant,

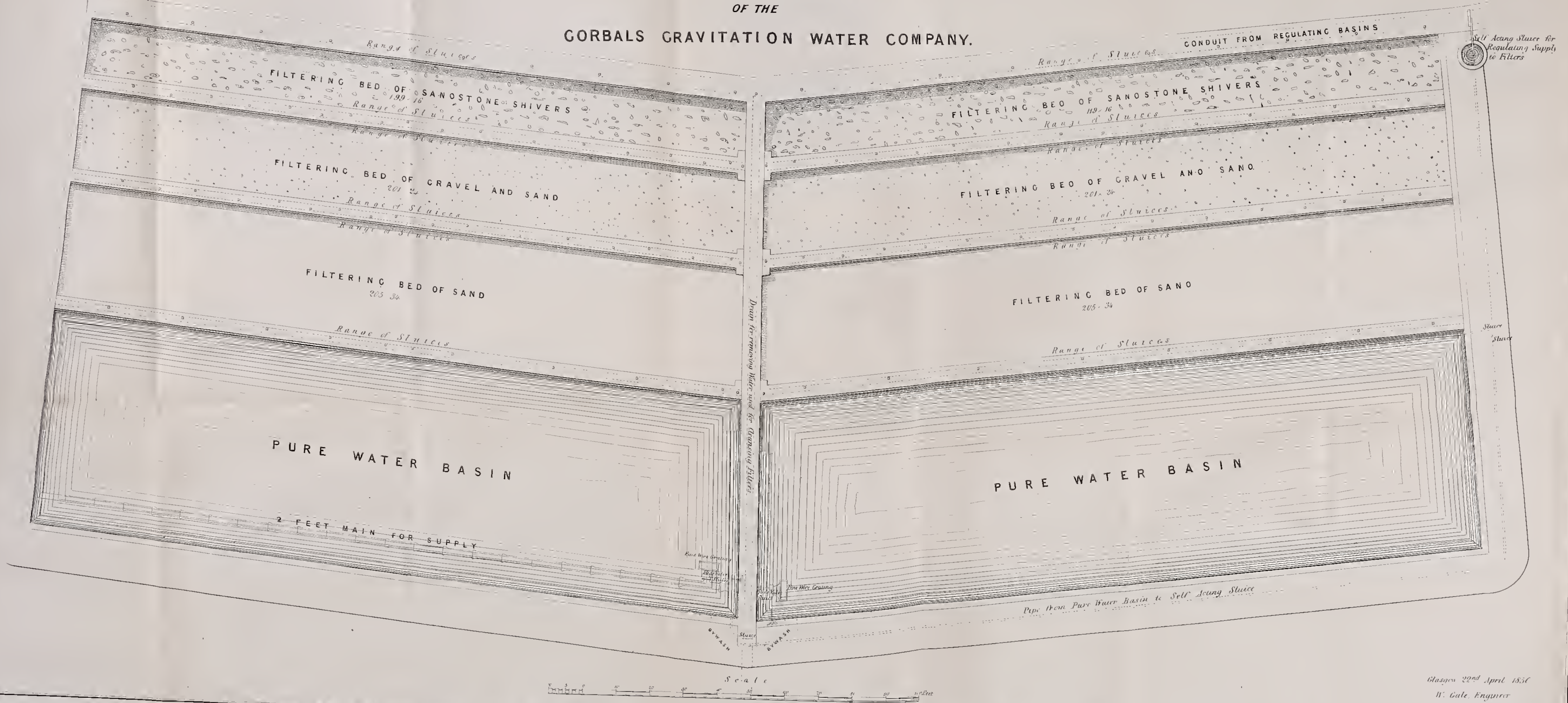
(Signed) William Gale.

Henry Austin, Esq.

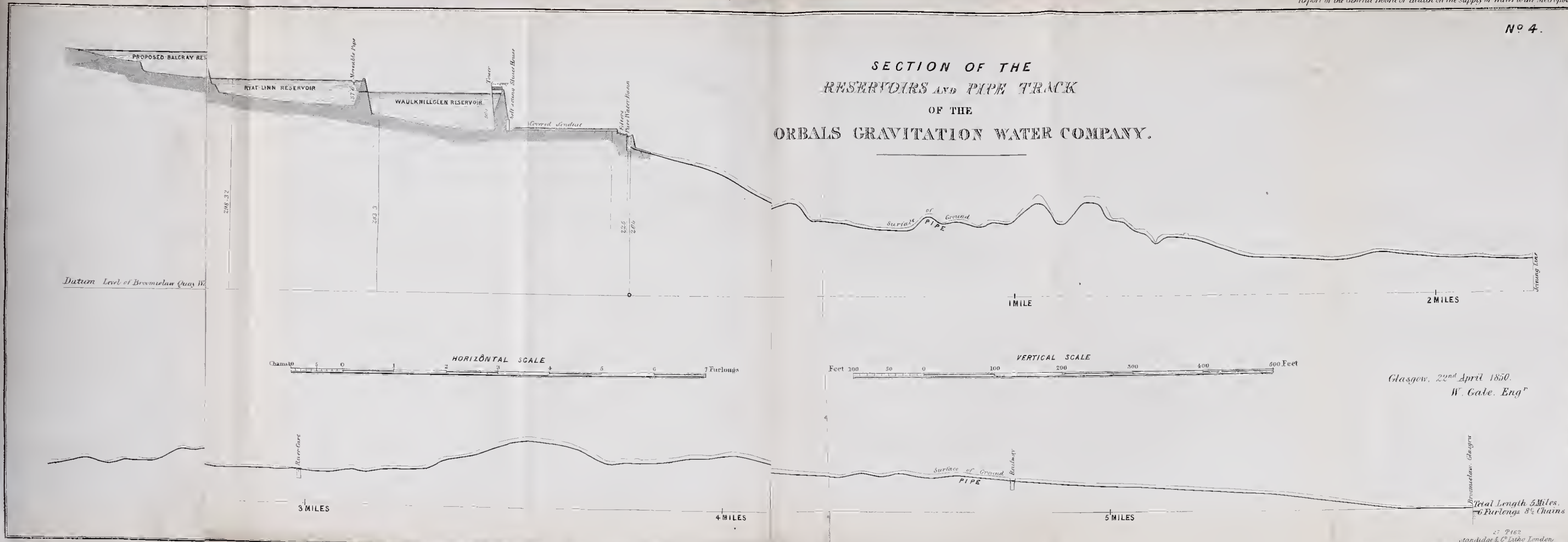

No 2.
SECTION,
SHOWING PART OF THE WORKS
OF THE
GORBALS GRAVITATION WATER COMPY
THROUGH LINE A.B.C.D. ON PLAN.
TOWER
GANGWAY
RESERVOIR
INLET
INLET
INLET
EMBANKMENT
SUPPLY PIPE
COMPENSATION PIPE
SELF ACTING SLUICES
REGULATING SLUICES
REGULATING BASINS
CONDUIT 340 YARDS LONG
CONDUIT
FILTERING BEDS
PURE WATER BASIN
SCALE.
Feet
ENLARGED SECTION OF
DIVISION WALLS OF FILTERS
BRICKS
PERFORATED TILES
CEMENT FLOORING
SCALE
Inches
Feet
Glasgow 22nd April 1850.
W. Gale, Engr.

No 3

PLAN OF FILTERS &c.
OF THE
GORBALS GRAVITATION WATER COMPANY.



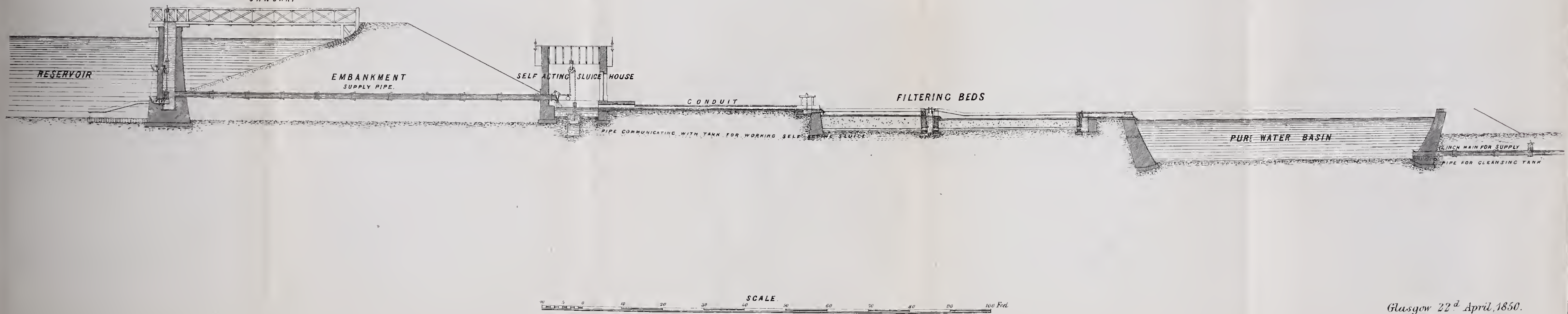
Glasgow 22nd April 1850
W. Gale. Engineer



Nº 4.
SECTION OF THE
RESERVOIRS AND PIPE TRACK
OF THE
ORBALS GRAVITATION WATER COMPANY.
PROPOSED BALGRAY RES
RYAT-LINN RESERVOIR
WAULKMILLGLEN RESERVOIR
Moveable Pipe
Tower
Self acting Sluice House
Covered Conduit
Filters
Pure Water Basin
298.32
283.3
226
204
Surface of Ground
PIPE
Datum Level of Broomielaw Quay W.
1 MILE
2 MILES
HORIZONTAL SCALE
Chains 10 5 0 1 2 3 4 5 6 7 Furlongs
VERTICAL SCALE
Feet 100 50 0 100 200 300 400 500 Feet
Glasgow, 22nd April 1850.
W. Gale, Engr.
River Cart
Railway
Broomielaw Glasgow
3 MILES
4 MILES
5 MILES
Total Length 5 Miles, 6 Furlongs 8½ Chains
Standidge & Co. Litho London.

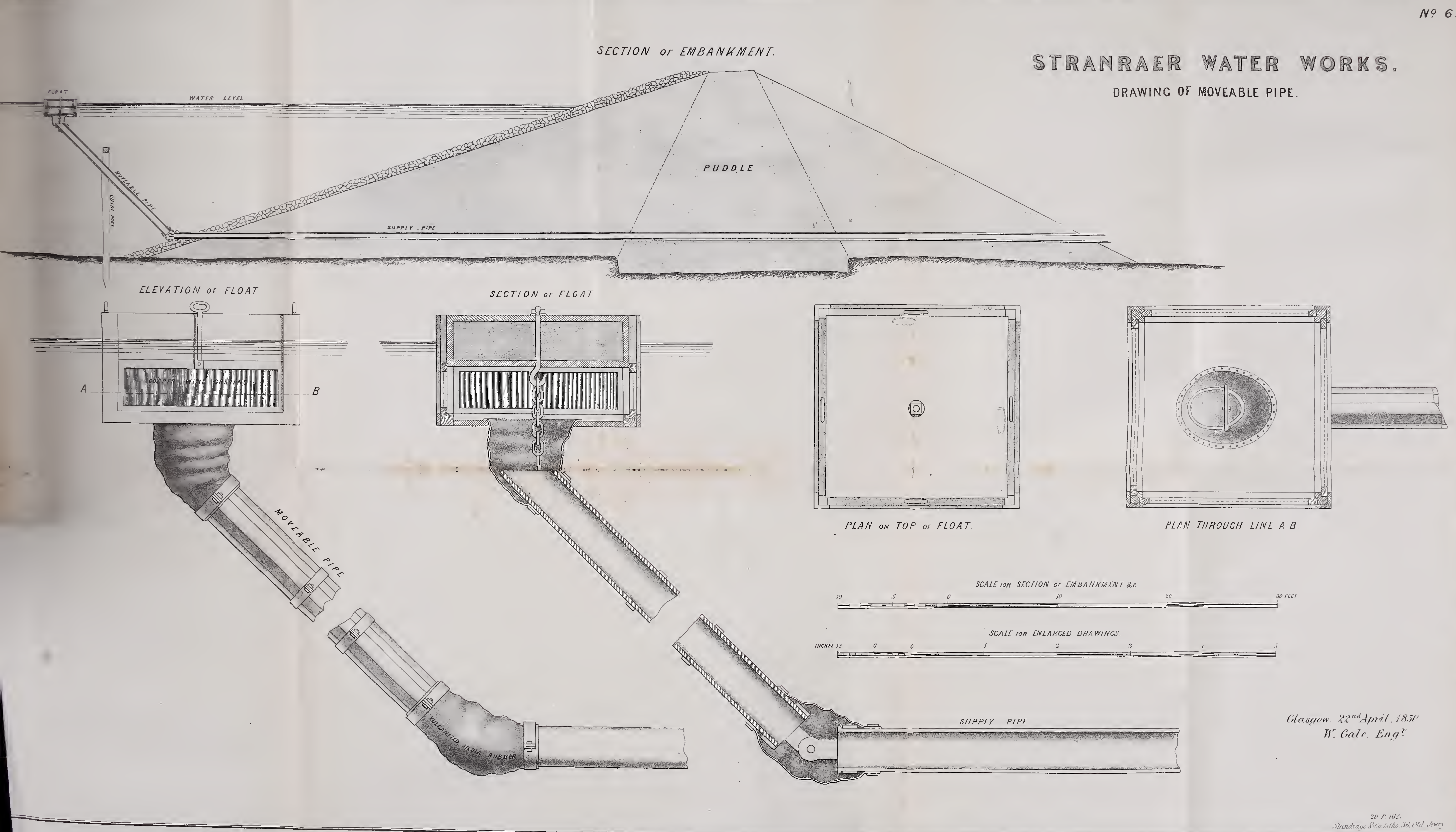
No. 5.

SECTION
SHOWING PART OF THE WORKS
OF THE
KILMARNOCK WATER COMPANY.



Glasgow 22^d April, 1850.
W. Gale. Eng^r

28 P 162
Standidge & Co Litho Old Jewry


Nº 6.
STRANRAER WATER WORKS.
DRAWING OF MOVEABLE PIPE.
SECTION OF EMBANKMENT.
FLOAT
WATER LEVEL
MOVEABLE PIPE
GUIDE POST
PUDDLE
SUPPLY PIPE
ELEVATION OF FLOAT
COPPER WIRE GRATING
A
B
SECTION OF FLOAT
PLAN ON TOP OF FLOAT.
PLAN THROUGH LINE A.B.
MOVEABLE PIPE
VULCANIZED INDIA RUBBER
SUPPLY PIPE
SCALE FOR SECTION OF EMBANKMENT &c.
10 5 0 10 20 30 FEET
SCALE FOR ENLARGED DRAWINGS.
INCHES 12 6 0 1 2 3 4 5
Glasgow. 22nd April 1850
W. Gale. Engr.
29 P. 162.
Standidge & Co. Litho. 36, Old Jewry.

ANALYSIS OF 17 SAMPLES OF WATER.

Saline and other matter in One Imperial Gallon of 70,000 Grains.	GRAHAM 1844			BRANDE 1846			PHILLIPS 1849			BOSTOCK 1834	BEALE 1841		BRANDE 1846				COLLEGE
	Greenwich Hospital.	Page's Well, Greenwich.	Lambert's Well, Deptford.	Brewery, London.	Charing Cross.	Royal Mint.	Camden Town Station.	Watford Station.	Tring Station.	Treasury Pump.	Robarts. Roehampton.	Robarts. Roehampton.	Thames, Chelsea.	River Colne.	New River.	River Lea.	TRAFALGAR SQUARE.
	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.	Grs.
Carbonate of Lime.	19.08	21.23	16.74	6.2	3.1	1.5	" "	19.54	14.72	34.3	48.0	24.0	16.5	18.1	14.7	10.2	3.27
Carbonate of Soda.	" "	" "	" "	11.7	14.6	12.0	17.60	" "	" "	" "	" "	" "	" "	" "	" "	" "	18.28
Sulphate of Soda.	3.62	0.60	2.67	24.2	19.6	18.1	13.0	" "	" "	" "	8.0	8.0	" "	" "	" "	" "	8.74
Sulphate of Lime. C Iron	0.52	" "	" "	" "	" "	" "	" "	0.94	1.09	16.1	32.0	24.0	1.5	1.2	1.6	6.2	" "
Muriate of Soda.	0.37	3.42	1.91	12.7	25.7	8.3	11.10	1.90	1.38	12.6	16.0	8.0	1.7	2.0	1.7	6.6	20.05
Carbonate of Magnesia.	" "	" "	0.84	1.1	2.4	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	2.25
Sulphate of Magnesia.	2.04	2.88	2.75	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	"	Sulphate of Potash		13.67
Carbonaceous Matter.	" "	" "	" "	" "	" "	" "	2.30	1.32	1.61	" "	" "	" "	t	t	1.2	2.4	0.68
Silica.	" "	" "	" "	0.4	0.7	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	0.97
Phosphates.	" "	" "	" "	0.4	t	t	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	2.03
Loss.	1.67	" "	1.33	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "	" "
Total	27.30	27.83	26.24	56.7	66.1	39.9	44.0	23.7	18.8	63.0	104.0	64.0	19.7	21.3	19.2	25.4	69.94

rederick Braithwaite

Mr. Braithwaite.

Frederick Braithwaite, Esq., M. Inst. C.E., examined.

How long has your attention been directed to the supply of water from wells?—Since 1835, when I succeeded my brother, John Braithwaite, I have been professionally engaged in obtaining supplies of water from wells. My father and grandfather, as also my brother, were for many years similarly engaged. The men employed were Doxey, sen., Doxey, jun., Powell, sen. (all dead), and W. Powell, jun., now residing at Hornsey-lane, Islington.

Chiefly in the metropolis, I believe?—Yes; and some distance round London, 15 to 20 miles. I have personally superintended the sinking and formation of the principal wells in London.

Will you put in a chart of the principal deep wells in London?—I will do so.

Will you mention the wells that you and your house have constructed?—

The Blackwall Railway, Minories.
Reid and Co., Liquorpond-street.
Greenwich Hospital.
Combe and Co., Castle-street.
Meux and Co., Tottenham-court-road.
Hanbury and Co., Brick-lane.
Barclay and Co., Southwark.
Calvert and Co., Thames-street.
Charrington and Co., Mile End.
Goding and Broadwood, Broad-street.
Hampstead Water-works.
Conservative Club, St. James's.
Union Club, Pall-mall.
Ravenhill and Miller, Glasshouse-street.
Weiss, Strand.
Potts, Vinegar-yard, Southwark.
Russell and other squares.
Hodgson and Abbott, Bow.
Deany and Henley,
Kingston Union,
Robarts, Roehampton, } Superintended as altered.
Durant, Putney,
Barnett.
Bridgewater, Countess of.
Bricheno, Skinner-street.
Richmond, Ratcliffe.
And many other smaller wells at Cobham, Leatherhead, Hertfordshire, and other localities.

Have you any sections showing the different strata passed through in sinking wells in the metropolis?—Yes; and I have sent some for the inspection of the Honourable Commissioners. I would refer them to a particular set of samples of the different strata passed through in sinking the well at the Minories, which I had the honour of presenting to the Museum of Economic Geology.

At what depth did your borings commence, and to what depth were

Mr. Braithwaite. they carried, in the several wells referred to?—At Messrs. Meux and Co.'s, Tottenham-court-road brewery, the well had been sunk into the chalk to a depth of 40 ft., yielding 30 gallons of water per minute; a boring to a further depth of 229 ft. only yielded 10 gallons per minute. Tunnelling was then adopted in the direction of the fissures in the chalk, when the total quantity of water obtained was 100 gallons per minute, since which the supply has fallen off, and the tunnelling has been twice extended, obtaining an increase of 1-5th. This well originally had an abundant supply of water from the sand-spring, *now dry*. This remark will apply to many wells in London. This well is dug to the chalk 156 ft., in the chalk 40 ft., and bored 229 ft.; total depth 425 ft.

Greenwich Hospital well was sunk to the chalk 123 ft. 6 in. from the surface, dug 30 ft. in the same, and then bored 100 ft.; in all 253 ft. 6 in. deep. The peculiarities of this well are, that there is only about 4 ft. of plastic clay, and no blue clay: that the land-spring is comparatively inexhaustible; it rises to within 14 ft. 6 in. of the surface, and ebbs and flows with the tide 2 ft. 6 in.; it extends to a depth of 35 ft. in Thames shingle or ballast. The sand-spring very abundant; but not more than 60 gallons of water per minute could be pumped *free of sand;* this spring rises to 11 ft. 9 in. from the surface, and ebbs and flows 3 ft. each tide. The chalk-spring was not so abundant, yielding only 120 gallons per minute at 58 ft. from the surface; ebbs and flows 4 ft. 6 in.

Professor Graham's Report.

"The water of the three wells is decidedly hard for deep wells in which the water comes from below the deep clays; being harder by one-half at least than Thames water, &c. &c.

"Several of the deep wells about London which I have had the opportunity of examining are softer than Thames water; and the only reason I can give for it is their greater depth than the Greenwich wells.

(Signed) "THOMAS GRAHAM."

I hand in an analysis of three waters taken from bored wells to the chalk at Greenwich and Deptford, made by Professor Graham at the same time.

Page's Brewery, Greenwich.
In 1 gallon 70,000 grains.

	Grains.
Carbonate of lime	21·23
Sulphate of magnesia	2·88
Sulphate of soda	0·60
Chloride of sodium	3·12
Solid matter	27·83

Lambert's Brewery, Deptford.
In 1 gallon 70,000 grains.

	Grains.
Carbonate of lime	16·74
Carbonate of magnesia	0·80
Sulphate of magnesia	2·75
Sulphate of soda	2·67
Chloride of sodium	1·91
Loss	1·33
Solid matter	26·20

Page's Well.

Feet.	
124	to the chalk.
152	bored in ditto.
276	total depth.

Lambert's Well.

Feet.	
55	to the chalk.
123	in chalk bored.
178	total depth.

Mr. Braithwaite.

Greenwich Hospital.
(1 gallon 70,000 grains.)

	Grains.
Carbonate of lime	19·08
Carbonate of iron	0·52
Sulphate of magnesia	2·04
Sulphate of soda	3·62
Chloride of sodium	0·37
Loss	1.67
Solid matter	27·30 in one imperial gallon.

N.B. Iron cylinders were used throughout.

Reid's well.—Cylinders carried down and into the chalk, which is 135 ft. from the surface; excavations in the chalk continued to a depth of 178 ft. from the surface, increasing the diameter of chalk well to 16 ft. 6 in., when it was continued at those dimensions to a further depth of 24 ft. (202 ft.) Up to this point only 50 gallons per minute of water was obtained. At 196 ft. a tunnel 7 ft. by 6 was driven 96 ft. A second was driven 120 ft., 6 ft. by 4, producing a further increase of 10 gallons per minute from No. 1 tunnel, and of 37 gallons per minute from No. 2 tunnel. A boring was then made 20 ft. deeper, which yielding an increase of 7 gallons per minute, a 7-ft. shaft was carried down, and two more tunnels, one 96 ft., and the other 24 ft. 6 in., in the direction of the fissures, giving an increase of 116 gallons per minute; producing in all not 200 gallons per minute. Cost 7000*l*. Superficial feet of chalk exposed in this well, about 1600 ft. N.B. Of this well it may be remarked, that, like many others, there was originally a large quantity of water in the sand-spring; in fact, nearly as much sand as water was injuriously raised. The house, before the sinking of the above well (1841) had the supply from the New River Company, and, in consequence of the falling off of the supply in the new well, recourse has been again had to the Water Company. During the progress of sinking this well I tried experiments on the *absorbing* powers of the chalk taken immediately above and below the fissures. I send the table.

A Table showing the Weight of Water absorbed by a given Weight of Chalk taken from above and below the Fissures at different Depths.

At 27 ft. deep. Above the fissure a piece of chalk weighing 9 lbs. 15¼ ozs., after 72 hours' drying, lost 10¼ ozs.

Below the fissure, weighing 10 lbs. 10 ozs., after 72 hours' drying, lost 16½ ozs.

At 53 ft. deep a piece weighing 3 lbs. 9 ozs., after 72 hours, lost 11 ozs.

Below the fissure a piece 4 lbs. 15 ozs., after 72 hours' drying, lost 1 lb. 1 oz.

At 68 ft. deep a piece above the fissure, 12 lbs. 3 ozs., after 72 hours, lost 2 lbs. 3 ozs.

A piece below fissure, 10 lbs. 9 ozs., after 72 hours, lost 1 lb. 15 ozs.

Specific gravity of chalk 2781.

Messrs. Combe and Co.'s two wells at the brewery, Castle-street, Long-acre.—In consequence of the rapid decline of the water in the sand-

Mr. Braithwaite.

spring (173 ft. deep) in the new well, and the expense of obtaining water from the sand-spring in the old well, which, from pumping too much sand some years ago, had fallen in at the bottom, the house determined to bore to and into the chalk, which is 223 ft. from the surface. A boring was at first carried down 100 ft., the stated depth by certain authorities where the "great water-bearing stratum" was to be found, but with little or no success; the boring was continued to 300 ft. in the chalk, in all 523 ft. from the surface, still with a trifling supply of not more than 20 gallons per minute. N.B. The new well being provided with an accurate gauge enables me to furnish the Commissioners with the accompanying table of the decline of the water in the sand-spring from July 1837 to December 1849. The table has been compiled monthly:—

If the Commissioners should require it, I can with pleasure furnish them with many more details of borings in the several wells I have previously named.

How far do you think the deductions to be drawn from the facts which have occurred under your own observation, conform to the prevalent views of geologists or of the projectors of Artesian wells?—I am of opinion that the result of my observations warrants me in conforming to the views of Dr. Buckland and other geologists, who consider the water in the deep springs under London or of the London basin as exhaustible, and that, comparatively, in a very rapid degree. I therefore differ with the projectors of the Artesian wells, who are, in my opinion, led into error by the partial success of wells sunk in a deeper part of the assumed basin. I allude more particularly to the *three wells* sunk, one opposite the National Gallery, and two others in Orange-street. If I may be permitted to digress, I am of opinion the Commissioners should obtain *correct* information touching these wells. But I wish it to be distinctly understood that I admit that there is still a large quantity of water in certain localities both in the land and sand springs, but I entertain serious doubts if any large quantity of water is to be obtained from the chalk under the metropolis, for in several of the chalk-spring wells, although but *recently* sunk, the water is sensibly declining.

What has been the success of the Hampstead Water-works?—The first well was sunk by my brother on the hill by the side of one of the upper ponds to the sand-spring 336 feet deep. A 12-horse engine was erected, and for some considerable time there was a good supply, but the pumps were only worked in times of deficiency in the surface-waters. Since then, in consequence of the falling off of the water, Mr. Mylne was employed to sink another well to and into the chalk. I am informed that the well is dug 321 feet to the chalk, 255 feet in the chalk, with a very short supply, and that he is now boring for more water.

What are your recorded observations of the effect of the pumping and the deep working at one part of the metropolis upon another?—Several. The most remarkable instance is now in operation. The pumping at the wells near Trafalgar-square is drawing the water rapidly from Messrs. Combe and Co.'s well, the Union and Reform Clubs' wells, and others. That at Combe and Co.'s, before the sinking of the Trafalgar-square wells, produced the same effect upon Covent-garden well, for until the pumps were lowered in that well, which I had advised to be done in the first instance, the engineer was compelled to pump two or three hours

TABLE

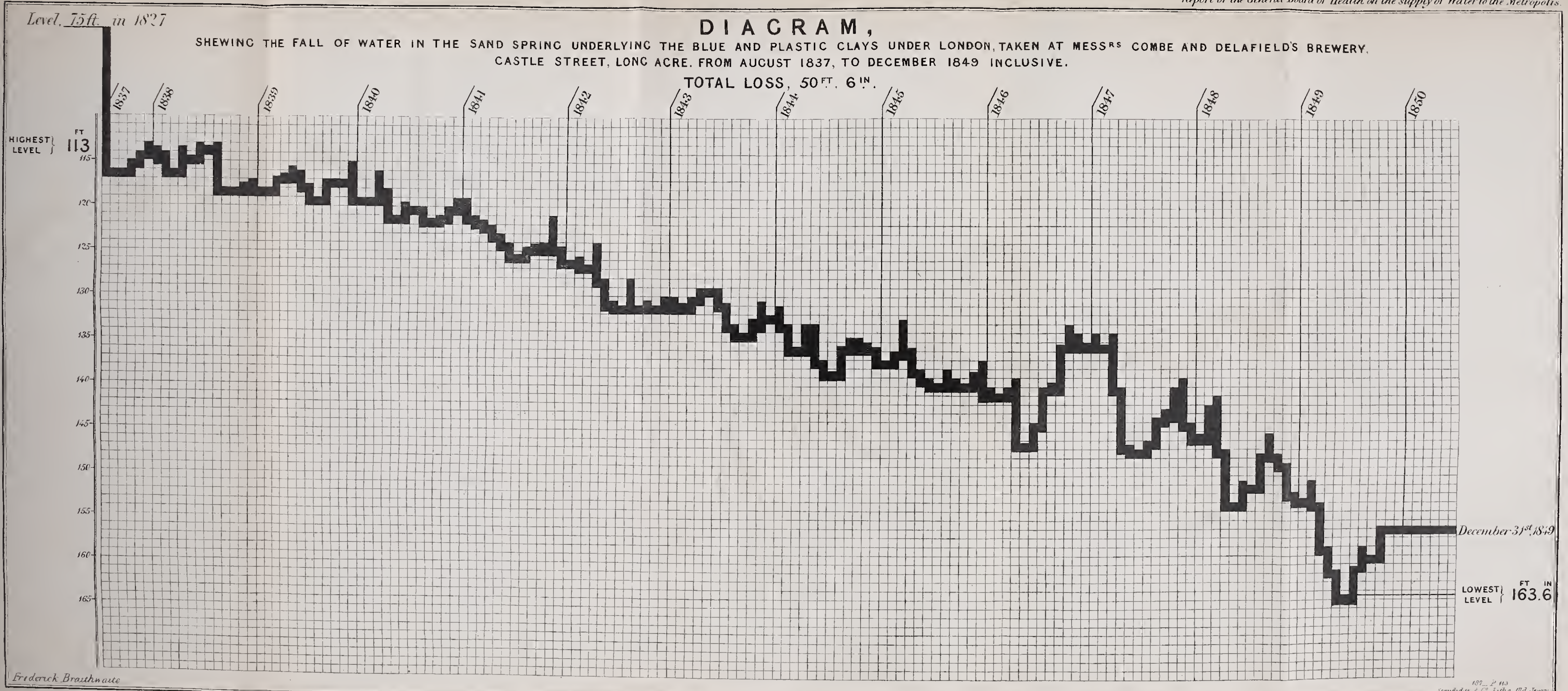
SHEWING THE DECLINE OF, AND THE EFFECT OF PUMPING ON THE WATER IN THE SAND SPRING UNDERLYING THE BLUE AND PLASTIC CLAYS IN LONDON, TAKEN FROM MESSRS COMBE'S BREWERY, CASTLE STREET, LONG ACRE, BEING 173 FT DEEP.

Water Level in 1827 – 75 Feet from Surface.

	1837	1838	1839	1840	1841	1842	1843	1844	1845	1846	1847	1848	1849
	Ft In	Ft In	Ft In.	Ft In	Ft In	Ft In.	Ft. In	Ft In	Ft In.	Ft In	Ft In	Ft In	Ft In
January.	„	113 . 6	118 . 0	119 . 0	119 . 0	126 . 0	130 . 0	131 . 0	137 . 0	140 . 0	133 . 8	139 . 0	148 . 6
February.	„	114 . 0	118 . 0	119 . 0	121 . 0	125 . 9	130 . 9	133 . 0	136 . 0	140 . 9	134 . 8	144 . 0	150 . 9
March.	„	116 . 0	116 . 9	116 . 0	121 . 6	126 . 6	130 . 0	135 . 6	132 . 6	140 . 0	133 . 11	145 . 3	152 . 6
April.	„	113 . 6	116 . 6	118 . 0	122 . 0	124 . 0	129 . 0	133 . 0	135 . 9	139 . 0	135 . 2	142 . 0	150 . 9
May.	„	114 . 6	115 . 9	121 . 0	123 . 0	128 . 0	129 . 0	133 . 0	138 . 0	146 . 6	135 . 11	141 . 0	153 . 0
June.	„	113 . 0	116 . 0	119 . 6	124 . 0	130 . 6	129 . 0	137 . 0	139 . 0	142 . 9	139 . 10	147 . 0	158 . 0
July.	116	113 . 3	117 . 6	120 . 0	125 . 6	131 . 0	130 . 9	138 . 3	139 . 6	146 . 3	146 . 6	153 . 0	160 . 9
August.	116 . 0	113 . 0	119 . 0	120 . 0	124 . 6	128 . 0	133 . 0	135 . 6	138 . 0	144 . 3	147 . 0	150 . 9	163.6
September.	116 . 0	118 . 0	117 . 0	121 . 6	124 . 3	131 . 0	134 . 0	134 . 6	139 . 0	140 . 3	146 . 0	151 . 0	160 . 6
October.	115 . 0	118 . 0	117 . 0	121 . 0	124 . 0	130 . 6	132 . 6	„ „	139 . 6	139 . 6	143 . 6	147 . 6	158 . 0
November.	114 . 0	117 . 6	117 . 0	120 . 0	121 . 0	131 . 0	130 . 6	135 . 0	138 . 3	135 . 3	142 . 6	145 . 3	159 . 0
December.	113	117 . 0	115 . 0	119 . 0	124 . 6	130 . 0	132 . 0	135 . 6	137 . 0	133 . 0	140 . 0	147 . 6	155 . 9

Frederick Braithwaite, Jany 29th 1850.

Standidge & Co. [illegible]


DIAGRAM,
SHEWING THE FALL OF WATER IN THE SAND SPRING UNDERLYING THE BLUE AND PLASTIC CLAYS UNDER LONDON, TAKEN AT MESSRS COMBE AND DELAFIELD'S BREWERY, CASTLE STREET, LONG ACRE. FROM AUGUST 1837, TO DECEMBER 1849 INCLUSIVE.
TOTAL LOSS, 50 FT. 6 IN.
Level, 75 ft. in 1827
HIGHEST LEVEL } FT 113
LOWEST LEVEL } FT IN 163.6
December 31st 1849
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
115
120
125
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165
Frederick Braithwaite
Standidge & Co. Litho Old Jewry

Mr. Braithwaite

before Combe's pumps began work. There are several other recorded instances. The effect of Barclay's pumping on Calvert's well; in fact, there has been one universal depression in all the wells to the sand-spring, varying only in degree according to the various depths. I may mention two instances not exactly in the metropolis. The one occurred at the brewery of Messrs. Tritton at Wandsworth, where the well, drawing the supply from a neighbouring well (Mr. Rutter's), was the subject of a lawsuit. The other occurred at the Kingston union well, sunk to the sand-spring 425 feet, where the water rose to within 7 feet of the surface, which, when lowered by pumping to 25 feet, affected Mr. Palmer's well, which was about 200 yards distant, also sunk to the sand-spring. Mr. Palmer's well is situated something lower than that at the union, and was really *an Artesian well, for it overflowed;* but when the water at the union well was lowered, as above stated, it (Palmer's well) ceased to do so. This discovery led to the correction of an important error; it was always stated that Mr. Palmer's well-water was from the chalk, but it is only from the sand.

Are there many of the domestic wells remaining?—I think there are; but many of them have lost a considerable portion of their supply, arising from the construction of the deep sewers cutting into and through the first bed of gravel, in which the land-springs are or were found.

Will you state the nature of your proofs to show that the Thames water really does affect the well-springs?—The proofs I adduce are three: 1. The well at Greenwich Hospital, where, as I have previously stated, the land, sand, and chalk springs are *tidal.* 2. The fact that in 1832 the water in 10 of the principal wells in London rose to and stood at the level of Trinity high-water mark, but does not now rise to the same level within 50 and more feet. 3. The fact that the water of the *deep wells* is found, upon a recent analysis, to contain considerably more saline matter than heretofore. I hand in a table of the analysis of seventeen different waters; the red figures denote those of the deep wells under London.

It is stated that, in the course of digging some time since on the premises of the Vauxhall Water-works for the formation of a reservoir, an enormous supply of water was found, which was very clear, but possessing chalybeate qualities, and was totally distinct from the Thames water?—I am not aware of that fact.

Will you put in any illustration of the evidence of this tidal effect upon the wells?—I have done so; but ocular proof may be obtained at the well at the brewery of the Royal Hospital, Greenwich. It will be only necessary to ask the authorities to allow the pumping to be discontinued a few hours.

Were these waters analysed?—The chalk-water was analysed by Professor Graham, and I have given the analysis. The sand-water was also analysed, but I have not the analysis. I understood there was little difference between that and the water from the chalk. The land-water is very hard indeed.

It appears that the brewers, who can avoid it, never use the Thames water?—My opinion is that the preference shown to well water is on account of its temperature, varying, summer and winter, from 52° to

Ir. waite.

54° only; which enables the brewers (being able to refrigerate the worts) to brew all the year round, with a large economy in hops.

Then you think it is temperature, rather than quality, that the porter brewer requires in the water?—Confining the question to well and river water, I think it is: for I do not consider there is any material difference in the quality; it is true that the well-water is more filtered.

Will you put in an analysis of the Greenwich well?—I have done so.

It is said that the water of the well in Trafalgar-square is only 4 or 5 degrees of hardness, and that it is not more than one-third the hardness of the Thames water. Supposing that to be so, would not the different solvent powers of hard and soft water make a great difference in the respective value of such water?—I presume degrees of hardness refer to Dr. Clark's table, where each degree represents *one* grain of carbonate of lime in one imperial gallon of 70,000 grains; if so, then it would appear that there are from *four* to *five* grains of carbonate of lime in the well-water of Trafalgar-square, and 12 to 15 grains in the Thames water. If the carbonate of lime in the well-water of Trafalgar-square had been thrown down by Dr. Clark's process, then it would have been rendered comparatively the more valuable; but when, as is no doubt the fact, the carbonate of lime has only been replaced by a large admission of soda and other salts (namely 66 grains), I am justified in attaching the greater value to the river Thames water. For *washing* purposes the well-water may be preferred.

Of course, the sand-spring water is artificially filtered. Is not that an advantage on its side?—Clearly so.

What would be the expense of one or more of these larger deep wells?—

	Messrs. Reid's cost . . .	7,000*l.*
	Blackwall Railway . . .	8,000*l.*
Published	New River	12,400*l.*
	Hanbury's	5,795*l.*

It is difficult to state the cost of many of the deep wells in London; it may be said that many of them, more or less, have been a continued source of expense and trouble to the proprietors. The expense varies, for some of the wells have distinct engine-power, and some are worked by the engine of the establishment doing the general work.

Is the surface-water, as a general rule, softer or harder than the Thames water, whatever strata it may be obtained from?—If by ths term surface-water I am to understand it to mean land-water, I would observe that I have, I may say, found it always harder than the Thames water; and that the land-water I have found has been in the yellow gravel above the blue clay.

Can you show the extent of influence of one well over others?—This question has been answered.

Have you had any observations as far as Watford?—None beyond reading the Reports and controversies of Messrs. Stephenson, Clutterbuck, Dickinson, and others.

Supposing an impermeable drainage to be substituted for a permeable brick drainage, must it not be accompanied with permeable

drainage for the places requiring it on account of the damp?—Certainly; but the lower portions of the sewers in loose or made ground should be impermeable.

Mr. Braithwaite.

Mr. George Donaldson examined.

Mr. Donaldson.

You are one of the assistant engineers of the Metropolitan Commission of Sewers, specially conversant with land-drainage works?—I am.

You were directed to make examinations for the sanitary improvement of Richmond, Sydenham, Croydòn, Greenwich, and other districts near the metropolis, and in those examinations to include provision for improved water supplies for domestic use?—Yes, I was.

You have also been led by your avocations to make examinations as to the state of the surface soil and subsoil of large tracts near the metropolis, and the qualities of the waters with which they are charged?—Yes, I have done so all round the metropolis.

Within what distances?—Within 12 miles on the north, and from 25 to 30 miles on the south-east, south, and west.

To take one instance closely adjacent to the river Thames, that of Richmond; had you any instances there of drainage, or what may be more properly termed artificial spring water?—Yes; a large part of Richmond Park has been very efficiently drained, under the direction of Her Majesty's Commissioners of Woods and Forests; and from those works there arises a constant and copious supply of artificial spring water.

What is the nature of the soil?—It is a sandy or gravelly loam, incumbent in a clay subsoil.

What did you find to be the quality of the water derived from this surface?—It was perfectly clear; soft to the feeling, well aerated, and pleasant to drink.

Was it so clear as not to need filtration?—It was so clear, that I would not think of filtering it for drinking. It was more brisk than filtered water usually is.

What was the analysis?—There were several specimens from the tract of land drained. There was a large portion of water which had only three degrees of hardness. The average of six specimens was four degrees and one-third.

Would that have been the average of the bulk of all the water taken from the park?—I think the average of the bulk would have been about five degrees.

What at that point are you aware is the average degree of hardness of the Thames water which runs beneath Richmond?—I believe it is about 13 degrees.

That is to say, about three times as hard as the artificial spring water from the land close by?—Nearly so.

Had you any opportunity of comparing the surface water from the undrained portions with the shallow spring water derived from the portions drained?—Yes, several opportunities.

What were the characteristic differences?—The surface water generally holds in suspension earthy and other matters, taken up in passing over the surface.

Mr. Donaldson.

Did you get these surface waters analyzed?—No, I did not think it necessary for the purpose in hand. I am, from long observation, aware that water passing through a bed of vegetation does leave behind, not only the matter in mechanical suspension, but much of the matter in chemical solution. This is a point which has hitherto not received the attention which its importance deserves. I am quite sure that a bed of vegetation will detain for its food saline and other matter in solution, which no sand or other artificial filter will separate from the water. I have seen water, containing a considerable quantity of sewage from a farm-yard, which has passed upon well-drained pasture land, and the water which has drained through it has come out perfectly clear from the manure in solution.

Was it so clear that you would have drank it?—I have freely drank it. It had all the appearance, and tasted as perfectly pure spring water.

It is to be presumed, however, that there might be an extent of manuring or shallowness of the filter-bed of earth which would not detain the matter in solution?—No doubt of it. Wherever the drainage is shallow, and the quantity of manure excessive, no doubt some of it would be left in the water. In the case I referred to the drainage was from 3 feet to 4 feet in depth.

You were only understood as stating that filtration through a bed of earth would detain matter in solution which a common sand-filter or any other mechanical filter would not detain?—Clearly so; that is, when the surface of the land is covered with vegetation.

It accords with your observation, then, that shallow or artificial drainage water is of a superior quality and must generally be so, to ordinary surface water?—Decidedly so.

Does it also accord with your observation that it is superior to the common river water?—Greatly superior in purity to the common river water.

What is the extent of gathering ground for shallow spring water which the whole of the Richmond Park might afford when all drained? —The whole of the park is about 2,337 acres, of which nearly 2,000 acres might be made available as gathering ground.

What quantity of water might be derived from that 2,000 acres?—About 400 millions of gallons per annum.

What is the average rain-fall there?—I estimate the rain-fall at 25 inches, of which I think 10 inches may safely be calculated upon as the quantity which could be collected and stored.

Are there any local peculiarities to account for the deviations in the ordinary calculation of surface-water from rain fall, namely one-third the amount of the annual rain-fall? There are; the nature of the soil on the surface is such as to absorb water as it falls; also the nature of the subsoil which is such that very little will percolate so deep as to be lost.

Seeing the quantity of rain-fall which will be drained by the drainage of land, and the larger proportions obtained from gathering grounds than from the mere surface discharge of water, may not such gathering grounds be economically contrasted with the system of surface drains?—The effect of drainage is to make the ground more permeable and more absorptive, so that the water soaks into it more readily.

Mr. Donaldson

Then the water will not be detained there?—It will not evaporate from the surface.

Then there will be not only less loss from the surface from evaporation, but also less loss of temperature?—Clearly so.

Of course drainage improves vegetation, which is due as well to the matter left by the rain as to the action by permeation of the air?—I believe it is so.

Have you observed an advantage in this shallow spring water in its freedom from animalculæ as compared with other water?—I never met with animalculæ in spring water as it came from the spring or drain.

Take the case of Richmond, what number of houses would such a gathering ground as Richmond Park supply at the rate of 50 gallons per house per diem?

Have you estimated the extra value to each house if it were supplied with water of this quality, viz., one-third the degree of hardness of Thames-water, would it not be an immense saving in soap?—No doubt of it; but more specific information on this subject, derived from actual experience, is desirable.

Would you think it necessary to use any filtering remedies for such water?—I think it would be unnecessary if the reservoir were suitably made. The natural filtration through which it has passed is in my view superior to any artificial mode.

Were you not called in to report on the sanitary condition of Sydenham?—I was.

Did you find any surface-water there?—Not much worth notice. The land there is mostly clay, and the surface-water was hard and rather brackish, so was the water from the wells, and charged with a clayey colour. It would not answer for household purposes; a little beyond Sydenham, some half mile from the town I found a supply of only two degrees of hardness. I did not gauge the quantity, but think it would be sufficient for all Sydenham.

Is Sydenham within the jurisdiction of any water company?—Yes, of the South Lambeth Water Company.

Supposing you laid down a distributory apparatus for Richmond, at what cost could it be done per house?—Four pounds per house.

What was your estimate of the price at which it could be done for Sydenham?—Five pounds per house.

At Richmond did you design to distribute the drainage at the backs of the houses?—In a great number of cases, and also the water-supply where it was practicable, as a saving of a great length of pipe. The supply being near to the wash-houses where it is wanted.

What do you find the saving from back drainage to be as compared with front drainage?—As a general rule, it is something like 20 feet of house-drain pipe per house, and a proportionate saving in the length of water-pipe.

In general does it not save two-thirds of the distributory apparatus?—Nearly so; and it makes the apparatus itself more compact, and less liable to injury.

What is your estimate of what the water-supply could be furnished to Richmond for, per house, from the supply in the park?—Seventeen

Mr. Donaldson.

shillings and sixpence per house per annum would repay the whole outlay with interest in 22 years, and cover the cost of working and superintendence.

Suppose the population had the choice of the Thames River water or this shallow spring water, what would it be worth while for the inhabitants to pay per acre, if they could be supplied with 100 gallons per diem as compared with the supply of the river?—As affecting health the difference between pure spring water and the Thames water is above all price; as a matter of economy in washing and for other domestic uses, it would be worth an annual payment of three guineas per acre assuming the water not to exceed five degrees in hardness.

From several analyses and calculations as to the saving in soap by the use of soft water; and from inquiries I have made of numerous consumers, of the quantity of soap used per individual, it appears that for every 100 gallons of water used in washing, two ounces of white curd soap is required for every degree of the hardness of the water used.

Thus a water of 5 degrees hardness takes . .	10	ounces	of soap,
And one of 15 degrees hardness takes . . .	30	„	„

I find that 14 lb. per individual per annum is about the average consumption of yellow soap for washing and domestic use, and the price is about 5*d.* per pound. Therefore 100 individuals using water at 15

degrees hardness takes 1,400 lb. of soap at 5*d.* per lb. .	£29	3	4
And with water 5 degrees hard, 466 lbs.	9	14	3
Difference	£19	9	1

In round numbers the saving in soap by using water 5 degrees hard instead of 15 degrees is 20*l.* per 100 individuals, exclusive of the tear and wear of clothes from washing in hard water which will fully equal the saving in soap.

How many families at your estimate of the gathering grounds can be supplied per acre?—One inch deep of rain-fall on an acre will supply 10 cubic feet per day for a year, which I assume as a minimum quantity per house per diem. So the depth in inches of rainfall obtainable indicates the number of families it will supply during one year. The average rainfall being 21 inches, one-third of that would supply seven houses. Assuming the number of houses in the metropolis at 300,000, and assuming the rainfall per annum at 24 inches, one-third of that, = 8 inches, gives eight families per acre; at this rate it would take 37,500 acres, or 58 square miles of gathering ground. The irregularity of a rain supply necessitates large reservoirs, equal to three or four months supply. The cost of draining 37,500 acres, at an average of 6*l.* per acre, will be 225,000*l.*, which would amount to 12*s.* per house.

What were the charges of the London companies for supplying Sydenham with water?—Their works have not yet been carried out to Sydenham.

What is your estimate exclusive of house service?—At Sydenham 5*l.* per house, that is the capital expended.

What extent of ground having similar advantages with respect to

gathering grounds have you observed near the metropolis?—I am not aware of any ground possessing so many advantages as a gathering ground as Richmond Park, but there is a large extent of land within ten miles of the metropolis that might be made available for that purpose. Mr. Donalds

What is the total amount of acreage it would form?—About 10,000 acres.

Mr. Thomas Lovick, examined.

You are surveyor to the Metropolitan Commission of Sewers?—I am one of the surveyors. Mr. Lovi

And before, you had practical experience with branches of works that involved the consideration of hydraulics?—Yes, in surface drainage, plumbing, and house-drainage works.

Before you were appointed to your present office, did you not institute an investigation into the condition of numerous houses in your parish?—Yes, by the direction of the paving authorities of St. Andrew and St. George the Martyr, in whose employ I then was. I made an investigation into and reported upon the sanitary condition of many houses in these parishes.

In the course of your investigation did you examine the water supply?—Yes, there was a section in my Report devoted to this subject.

You were directed by the Survey Committee and the Works Committee of the Metropolitan Commissioners of Sewers to take certain gaugings and carry out certain trial works to show the quantity of sewage, or soil water, and other matter which passed through the house drains and sewers?—Yes: the principal gaugings which I undertook were in a sewer receiving the drainage from nearly 1200 houses, for the determination, chiefly, of the quantities of house sewage discharged at different periods.

Then you have executed part and are conversant with most of the trial works carried on under the consolidated Metropolitan Commission of Sewers to determine the quantity of water discharged by pipes of different diameters, construction, and inclination?—Yes, I am generally conversant with them; I have examined many of the results, the works relating to the flow through different sized pipes under different circumstances were not, however, under my direction.

Among other experiments were you not directed to ascertain the quantity of water consumed in a given block of houses, as shown by gauging the capacity of their butts and cisterns, and also the quantity of soil water discharged from the same block of houses through the sewers?—Yes; the block to which my instructions had special reference consisted of nearly 1200 houses discharging through one main line of sewer. By gauging in the sewers the quantity of water passing through them from the houses at different periods was ascertained; and by gauging the cisterns and butts in the houses the actual *consumption* of water was arrived at.

Were there not difficulties in getting a block of houses where such gaugings can be carried on with certainty as to the results? State the

r. Lovick. difficulties of getting a proper site?—There are few such areas to be obtained sufficiently large for an average deduction where all, or nearly all, the houses are supplied with water on the same days, so as to ensure with certainty the separation of the overflow or waste waters from the sewage; receiving the drainage of all or of a sufficient number of the houses; where the drainage can be traced with certainty to the point at which the experiments are to be carried on; where there is no interference with, or check of, the flow of the outlet sewer by contiguous main lines, or by the action of the tides penning in the flow; and where land or spring waters are excluded.

What is the time in which 100 gallons of water, stated as being a day's supply to some houses, may be discharged through a 3 and a 4 inch pipe at a minimum inclination of 1 inch in 10 feet?—With pipes 50 feet in length, full at the head, at the given inclination, this quantity would be discharged through a 3-inch pipe in three minutes, through a 4-inch pipe in one minute and a half.

What are the observed effects of junctions in the flow of the main line?—Greatly to increase the flow in the main line.

Give in a block plan with the "lineage" of existing drains.—I beg to hand in a block plan of Earl-street, with an approximation to the existing drainage marked thereon.

Were these houses you have mentioned of the middle class?—A great number were; some were of a higher class, many of a poorer class, but the average would be a medium middle class.

State the quantity of water that on an average you found to be consumed there per diem?—The average consumption, as ascertained from gauging the cisterns and butts, was about 5·7 gallons per individual per diem, or 51½ gallons per house per diem.

State the average quantity discharged per house per diem as produced from the gaugings of the sewers on days when there was no rain and no water supply?—44½ gallons.

State the average supply when the water was put on?—209 gallons.

From these gaugings did it not appear that the intermittent supply of water was twice as much as it need be?—The *mean* flow on the days when water was supplied to the houses by the company was nearly 4¾ times greater than the mean flow on the ordinary days, or days when there was no supply; the *excess* of the mean flow, or the flow due to the waste alone on the water days, would be nearly 3¾ times greater; but deducting the flow due to the ordinary drainage from the flow on the three water days, the waste would be three-fifths of the whole quantity supplied, and this would exhibit, leaving out of consideration the probable loss from absorption in both cases, the true relation of the consumption, as indicated by the gaugings in the sewer, to the waste. But as from the defects of the present system, from the numerous cesspools (at least 500 in this block), from the defective porous brick and mortar drains and sewers, a large amount of the flow must be absorbed in its transmission, both quantities, but more especially the waste, I have no doubt are much larger than the gaugings indicate. But leaving out any probable addition from this source, it appeared that the water supplied by the company was more than double the actual consumption, making the comparison between the flow in the

HYDRAULIC EXPERIMENTS. TABLE B.

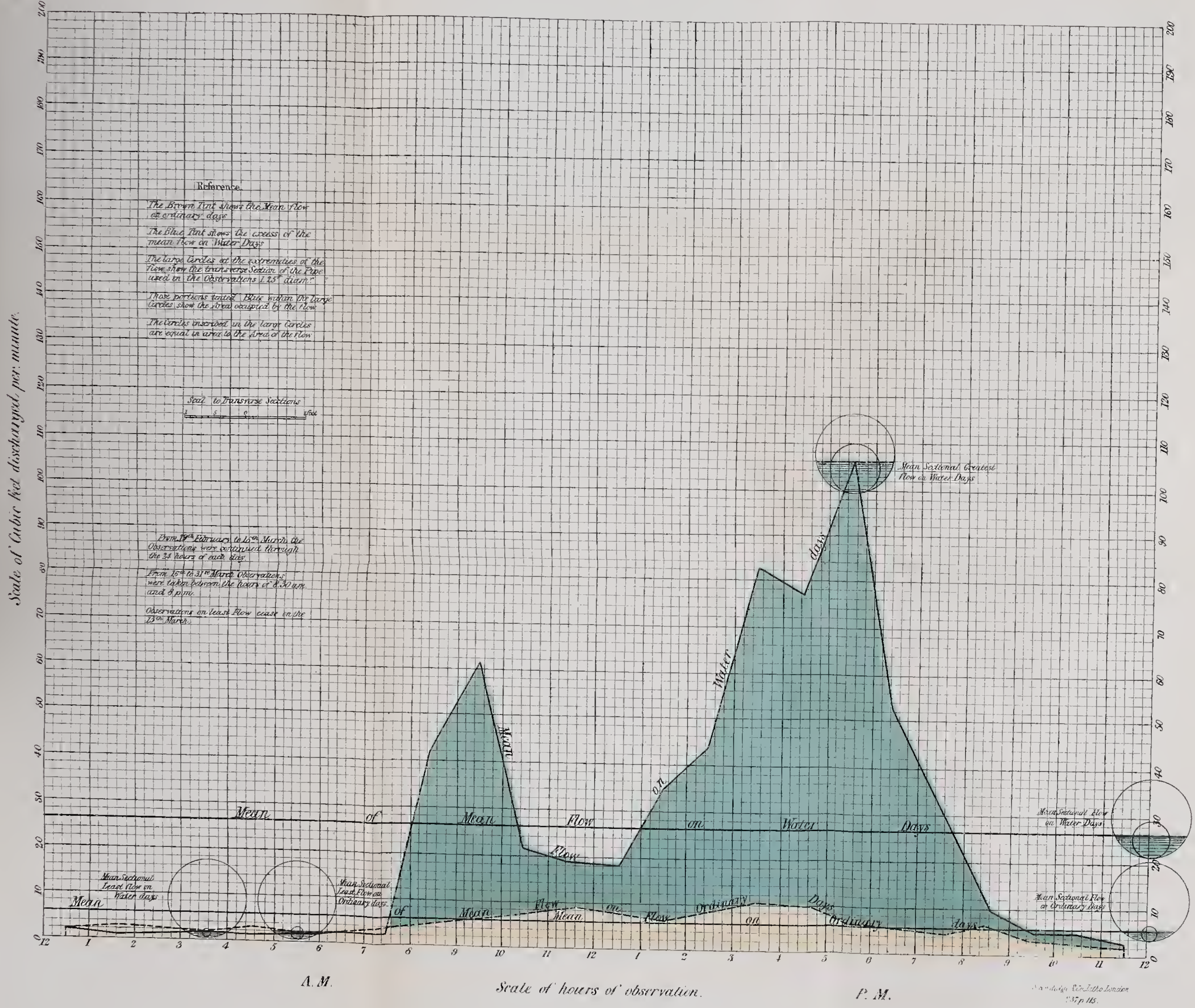
On Flow of Sewage through Glazed stone-ware pipes laid in the Earl Street Sewer.

Diameter of pipes 1.25 feet. Length of pipes 115 feet. Inclination of pipes 1 in 153.

Area draining into Sewer 43.656 Acres. Houses on Area drained 1315. Houses draining into Sewer 1155.

Mean flow due to House drainage only.

On Water Days mean of 16 Days observations. } *From 19th February to 31st March 1849.*
On Ordinary „ „ 14 „ „ }



Standidge & Co. Litho London
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HYDRAULIC EXPERIMENTS, TABLE A.

On flow of Sewage through Glazed stone ware pipes laid in the Earl Street Sewer.
Diameter of pipes 1.25 feet. Length of pipes 115 feet. Inclination of pipes 1 in 153.
Area draining into Sewer 43.656 Acres. Houses on Area drained 1315. Houses draining into Sewer 1135.
Shewing the greatest flow due to House drainage only.
From 19th February to 31st March 1849.

sewer on the two classes of days, as each would be subject to the same influences. Mr. Lovick

You have prepared, we understand, diagrams of the flow observed in this block; give them in?—The alternations of the flow are shown in the accompanying diagrams. Diagrams Nos. 1 to 30 exhibit the daily flow at the periods of observation. Diagram A exhibits the greatest flow on water and ordinary days with the contrasted least flow, with the sectional areas occupied by the flow in the pipe, with the inscribed equivalent circular sections placed at the correspondent points of discharge. Diagram B shows the mean hourly and mean flows on water and ordinary days with the sectional areas and equivalent circles thus shown, this information being common to the whole tabular series. The lower horizontal line represents the hour-line, or period of observation; the vertical lines the discharge in cubic feet per minute. The extreme and mean variations of flow with the areas occupied are shown in the annexed table:—

Days.	Quality of Flow.	Cubic Feet per Minute.	Sectional Area of Flow in Pipe.	Diameter of Circles equal in area to the sectional area of the Flow.
			Inches.	Inches.
On water days.	Least . . .	1·07	1·66	1·5
	Mean . . .	26·46	27·94	6·00
	Greatest . .	150·00	109·79	11·8
On ordinary days.	Least . . .	1·78	3·05	2·00
	Mean . . .	5·64	8·57	3·4
	Greatest . .	16·90	18·14	4·9

The maximum being greater than the minimum—on the water-days 140 times, on the ordinary days 9½ times.

Does it not appear that the waste water pumped into this district exceeds the annual rain-fall within that district?—The waste water sent into this district would be upwards of 4½ million cubic feet per annum. This quantity would cover the area draining to the outlet sewer to the depth of nearly 30 inches.

From your own observations, do not these results show the waste of water that may be presumed as taking place in other districts?—I have hardly ever observed the present intermittent water-supply unaccompanied by waste: it may indeed be said to be a concomitant of the system. The waste in other districts I have observed to be very considerable; but except in one or two instances I have no gaugings, so as to speak to the quantities.

Did it not appear that, notwithstanding this flow of water at the rate of 209 gallons, accumulations took place in the house-drains and sewers: accumulations which had to be removed by hand labour or flushing?—Yes. In order to ascertain the extent to which this took place, and the influence of the waste in the prevention of accumu-

Mr. Lovick. lations, I had the whole of the sewers connected with this block thoroughly cleansed immediately before the commencement of the experiments, and their condition noted at their conclusion, and analyses made of the flow at different periods on the ordinary days and on water-days. The results of these analyses are shown in the subjoined tables:—

Tables of Solid Matter in Suspension in the Flow.

No. 1.—*On the extra Water Days.*

Quality of Flow analysed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble.	Insoluble.	Soluble and Insoluble.	Soluble to Insoluble.	Soluble and Insoluble to Liquid.
	Grains.	Grains.	Grains.		1 to
Greatest, taken at $5\frac{1}{2}$ P.M. . .	33	19	52	2 to 1	1346
Mean of two analyses taken at 12 A.M.	119	46	165	$2\frac{1}{2}$ to 1	424
Mean of two analyses taken at $8\frac{1}{2}$ and $10\frac{1}{2}$ A.M.	119	37	156	$3\frac{1}{4}$ to 1	448
Least, taken at 12 P.M. . . .	111	11	122	10 to 1	574
Total	382	113	495		
Averages	96	28	124	$3\frac{1}{2}$ to 1	564
When water first laid on, or at commencement of overflow from cisterns	80	192	272	1 to $2\frac{1}{2}$	257

No. 2.—*On Ordinary Days.*

Quality of Flow analysed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble.	Insoluble.	Soluble and Insoluble.	Soluble to Insoluble.	Soluble and Insoluble to Liquid.
	Grains.	Grains.	Grains.		1 to
Greatest, mean of two analyses taken at 12 A.M.	114	34	148	$3\frac{1}{4}$ to 1	473
Mean, taken at $8\frac{1}{2}$ A.M. . . .	154	71	225	2 to 1	311
Least, taken at 12 P.M. . . .	114	14	128	8 to 1	546
Total	382	119	501		
Averages	127	40	167	$3\frac{1}{4}$ to 1	419

The approximate application of these results to the determination of the amount of solid matter passed in the flow may be thus shown.

Mr. Lovick.

On water days the flow per diem was 38,102·4 cubic feet. The average proportion of the soluble and insoluble matter to the flow on these days was 1 in 564; the solid matter passed in suspension being 68 cubic feet per day, in proportions varying from 1 in 424 at the mean, to 1 in 1346 at the greatest flow, and in varying proportions of the soluble to the insoluble matter of from 2 to 1 at the *greatest*, to 10 to 1 at the *least* flow. The water-days occur three times per week; the quantity of solid matter per week passed in suspension would therefore amount to 204 cubic feet. At the first commencement of the waste of water, or overflow from the cisterns, a remarkable difference is observed in the relative proportions, the solid then bearing a proportion to the liquid of 1 in 257, and the soluble to the insoluble of 1 to 2½—a result wholly at variance with the analyses at all other periods, which give *in every case* the soluble in far greater proportion to the insoluble, from a *twofold* to a *tenfold* ratio, thus showing an accumulation of deposit in the sewers or drains, or in both, which it required this increase of flow to set free. The mean flow per day on ordinary days was 8121·6 cubic feet, with an average of soluble and insoluble matter in suspension of 1 in 419; the solid matter passed in suspension being 19 cubic feet per day, in proportions varying from 1 in 311 at the mean, to 1 in 546 at the least flow; the two classes of solid varying from 2 of soluble to 1 of insoluble at the mean, to 8 of soluble to 1 of insoluble at the least flow. As there are four ordinary days per week, the quantity of solid matter per week passed in suspension would be 76 cubic feet. The whole quantity thus passed per week, or on the two classes of days—204 feet on the water-days, and 76 feet on the ordinary days—would be 280 cubic feet; the *quantity per day* on the water, as compared with the ordinary days, being upwards of three-and-a-half times greater, but of course less in proportion to, or more diffused in the flow. At the end of 31 days the sewers were found to have accumulated nearly 6000 cubic feet of deposit, or at the rate of 192 feet per day, and the accumulations in the drains must also have been considerable. But taking only the accumulation in the sewers, and assuming but *one-fourth* of this as *solid* matter, thus approximating it to the dry condition, as in the analyses, the quantity per week is 336 cubic feet; this, with the addition of the matter held and passed in suspension each week (280 cubic feet), would increase the amount of solid matter per week to 616 cubic feet, or, in proportion to the flow, of 1 in 238, the proportion deposited in the sewer being rather more than one-half of the total quantity. Thus it appears that the waste does exert a perceptible influence in the prevention of matter accumulated at ordinary periods, removing on the whole, taking it with the large reduction to its dry state, nearly three times more deposit than is passed in the ordinary flow; yet, notwithstanding, it is wholly insufficient to prevent far greater accumulations.

What is the present cost of keeping clear the sewer in Earl-street, by flushing and by hand labour?—The two systems—*keeping clear* by flushing, and *once cleansing* by hand labour and cartage—would hardly admit of a fair comparison. The flushing system is for the *prevention* of accumulations; the cleansing system waits for accumulations, and removes them (in general) only when the stoppage of the system

Mr. Lovick. compels it. This occurs in a great number of the sewers, notwithstanding the action of storms and of the waste water from the houses, which would periodically remove much of the lighter matter. But the quantity which had *accumulated* in the short space of time before named might be removed by flushing in this locality at about one-sixth or one-seventh of the cost of its removal by hand labour and cartage. But the cost of flushing, carried on as a *preventive* measure, would be at a much less rate.

Did you not, for the sake of the experiment, lay down in this sewer a 15-inch pipe; and with the same run of water did this 15-inch pipe keep itself clear?—For the purposes of the experiment, a 15-inch pipe was laid down in the sewer for a length of 115 feet, discharging into a tank formed to receive the flow. With the same run of water in the pipe as in the sewer, the pipe kept itself clear.

What is the probable sectional area of the drains in this block of houses?—596 feet.

What is the sectional area of the outlet sewer, and its proportion to the house drains?—The sectional area of the outlet sewer is 15 feet, or about one-fortieth the aggregate sectional area of the house drains.

Do you not consider that since the commencement of the Commission you have had sufficient experience of the run of water through 3 and 4 inch tubular house-drain pipes to speak with confidence of their power to keep themselves clear by the ordinary discharge of the soil-water or drain-water of the house?—A great number of small 4-inch tubular drains have been laid down in the several districts, some for considerable periods. They have been found to keep themselves clear by the ordinary soil and drainage waters of the houses. I would refer to 15 houses in the Cloisters at Westminster Abbey, which have now for upwards of 14 months been drained by small stoneware pipes, varying in diameter from 3 and 4 inches for the houses to 9 inches for the outlet, and which have acted and continue to act in the most perfect manner. I have been furnished by Mr. Morris of Poplar with accounts of blocks of houses in his district drained by small pipes: these are shown on the accompanying plans. No. 1 is a block of 12 houses in a court, six on each side; each six are drained *at the back* by one 4-inch pipe. They are connected with the closets, one to each house, to which the water *is not* laid on, the water being thrown down them by the inmates; the only other source of supply is from the overflow of the butts in the yards, yet the pipes have kept themselves clear from the period when first laid down, now upwards of 12 months since, to this time, and are still acting efficiently. Plan No. 2 shows various blocks with combined back drainage by small pipes. Some have connections with closets to which water is laid on; others take the overflow from privy cesspools; yet with all these disadvantages, and with the further one of inferiority in the pipes in the early manufacture, these combinations of back drainage have been, and are now, all in successful action; they have been laid down, in one instance for upwards of two years, in the majority for upwards of 12 months.

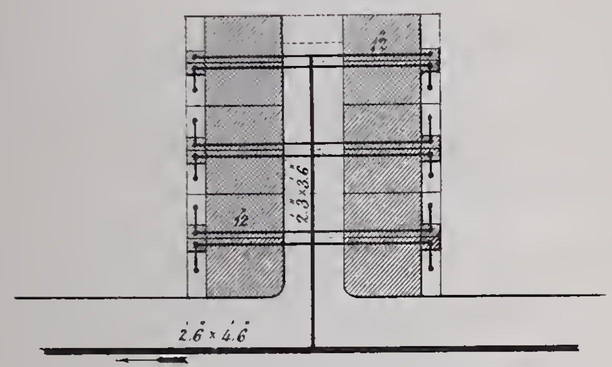
Then you have no doubt that pipes of this kind will keep themselves clear by the ordinary discharge of house-drainage?—I have not; as-

DRAINAGE OF COURTS, TOWER HAMLETS DISTRICT.

ORIENTAL TERRACE, POPLAR.

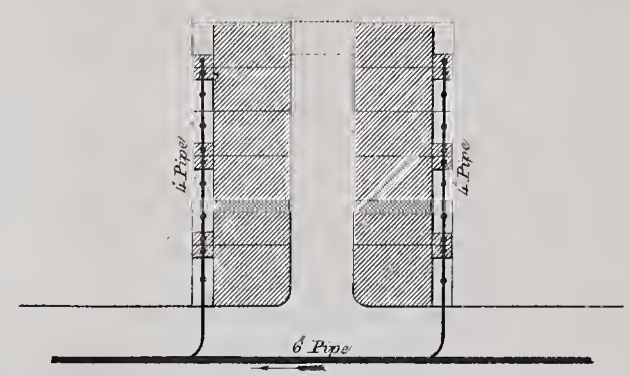
No. 1.

Old System.



No. 2.

Improved System, as executed in December, 1848.



BRICK SEWERS.

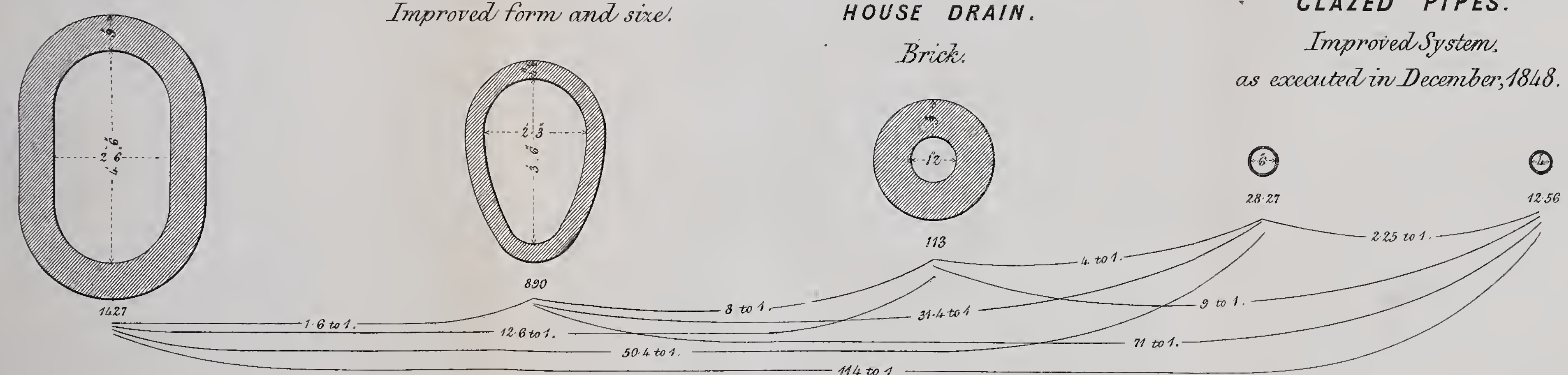
NOTE.

The figures on the curved lines indicate the relative proportions of the forms, or systems, connected by them; those under each section denote the areas in square inches.

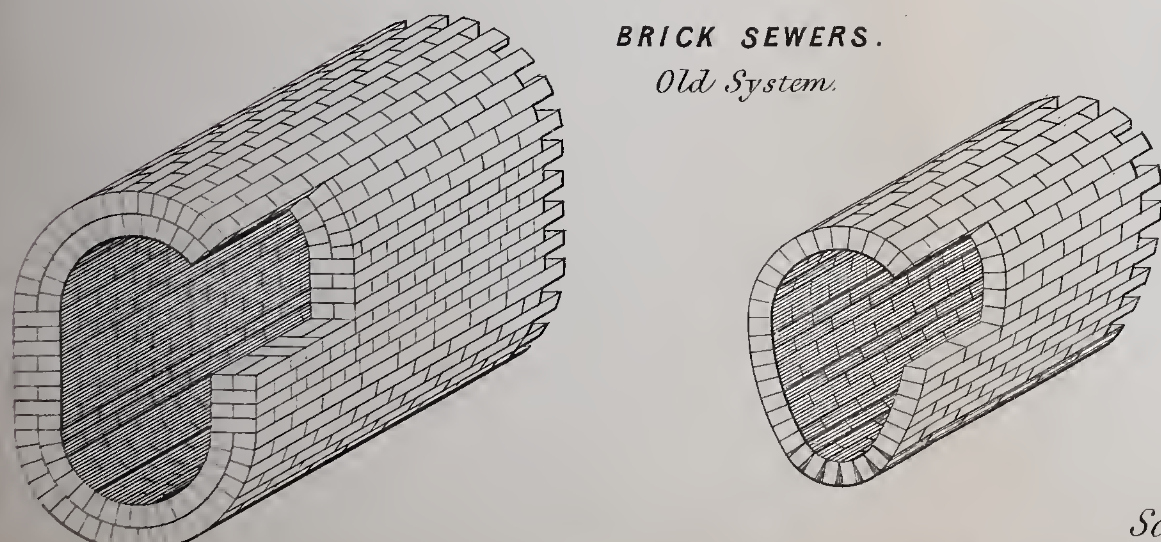
Old form and size. *Improved form and size.*

HOUSE DRAIN. *Brick.*

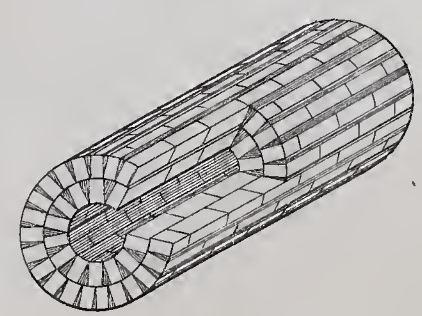
GLAZED PIPES. *Improved System, as executed in December, 1848.*



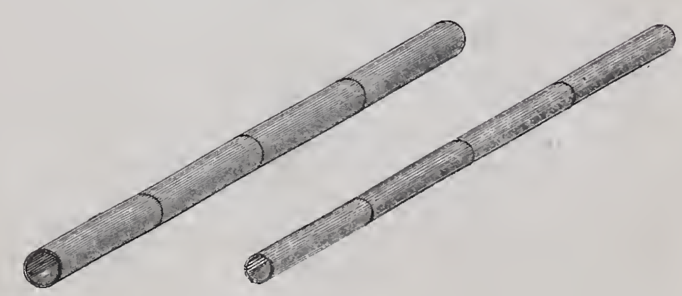
BRICK SEWERS. *Old System.*



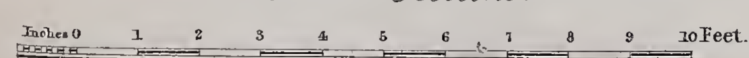
BRICK HOUSE DRAIN. *Old System.*



GLAZED PIPES. *Improved System, as executed in December, 1848.*



Scale for Sections.



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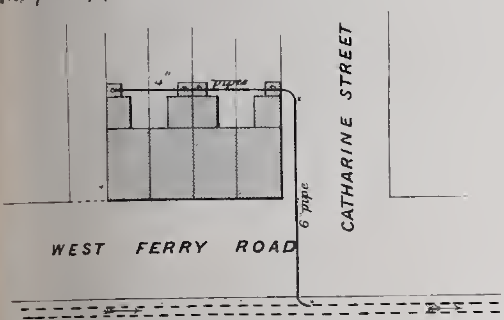
TUBULAR SYSTEM OF DRAINAGE.
POPLAR DISTRICT.

PLANS OF UNITED AND SEPARATE DRAINAGE BY 4IN & 6IN GLAZED STONE-WARE PIPES.

No 2.

Four Houses in the West Ferry Road Poplar, shewing the System of united back Drainage by 4 inch Glazed Stone-ware pipes, executed in October, 1848.

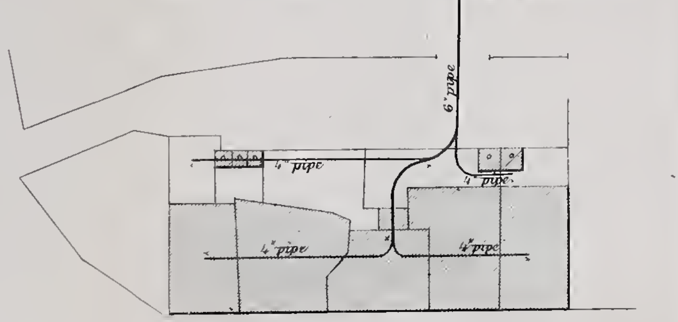


AREA OF PREMISES, 3600 FT

Inclination of outlet main 6 inch Pipe = 1 inch in 10 feet.
Do of 4 inch Pipes = 1½ Inches in 10 feet.
Average depth of Digging = 5 feet.
There are Pans to the Closets and connections from the Yards & Sinks. The Water is laid on

No 3.

Five Houses in High Street Poplar, shewing the System of united back Drainage by 4 inch Glazed Stone-ware Pipes, executed in September, 1849.

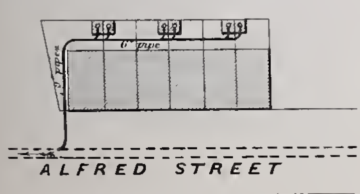


AREA OF PREMISES, 2400 FT

Inclination of 4 inch Drains - 1½ Inches in 10 Feet
There are Pans to the Closets, & connections from the Yards. The Water is laid on.

No 4.

Six Houses in Alfred Street, Poplar, shewing the System of united back Drainage by 6 inch Glazed Stone ware pipes, executed in September, 1847.

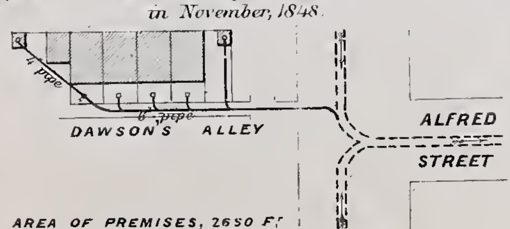


AREA OF PREMISES 2520 FT

Inclination of 6 inch Pipe = 1 inch in 10 feet
Average depth of digging = 5 feet
This Drainage takes the overflow from the Cesspools to the Privies in the Yards; there are no pans to the Privies. The Water is laid on to the Houses, but not to the Privies.

No 5.

Four Houses in Dawson's Alley, Alfred St Poplar, shewing the System of united back Drainage by 6 inch pipe & 4 inch branch Glazed stone ware pipes, executed in November, 1848.



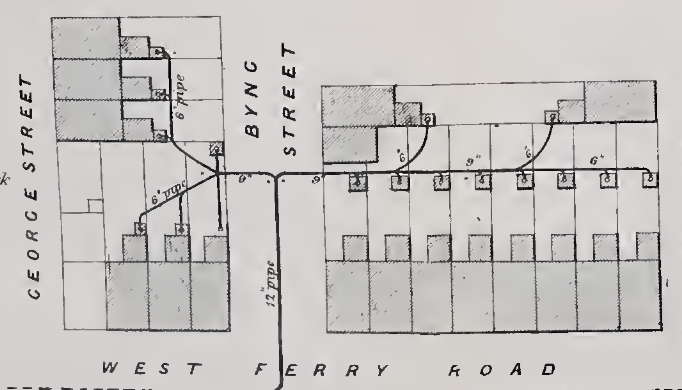
AREA OF PREMISES, 2650 FT

Inclination of 6 inch Main Pipe = 1½ Inches in 10 Feet
Average depth of Digging = 6 feet
There are connections from the Yards and from two Closets; no Pans to the Closets. The Water is laid on to the Houses, but not to the Closets or Privies.

No 6.

No 6.

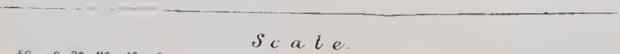
Sixteen Houses in the West Ferry Road, Poplar, shewing the System of combined back Drainage by 12, 9, & 6 inch Glazed Stone ware Pipes, executed in September, 1848



AREA OF PREMISES 22500 FT

Inclination of Drains 1in in 10 feet.
Average depth of Digging - 6ft 6in
To 15 Houses there are connections from the Yards & Closets, the Closets have Pans, & the Water is laid on.
To one House, Mr Allen's, the Drains take the overflow from the Cesspools; no Pan to Closet; there is a connection from the Yard. The Water is laid on to the House, but not to the Privy.

Scale.



Standidge & Co Litho. London.

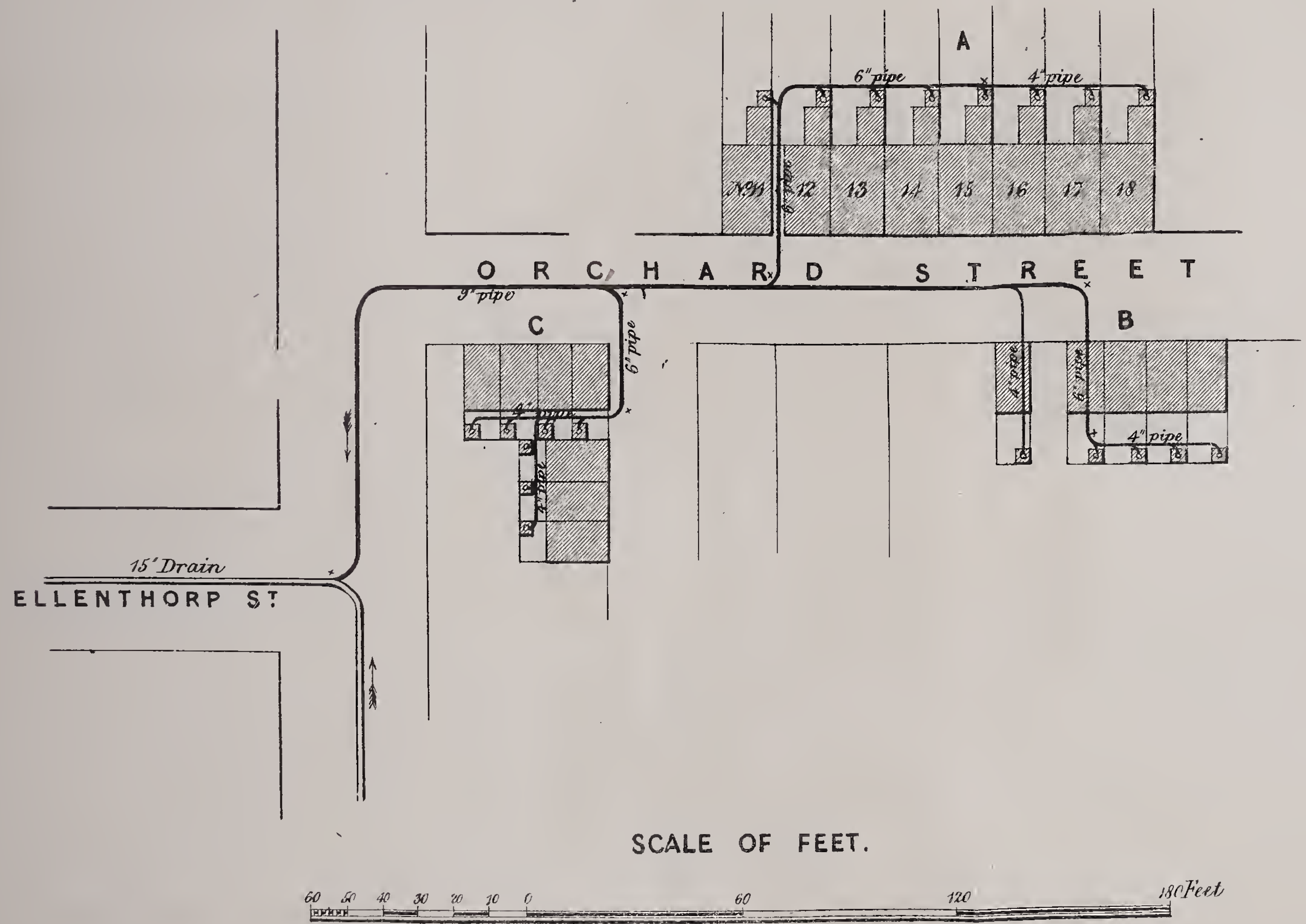
PLAN OF COMBINED BACK DRAINAGE;

ORCHARD STREET, POPLAR.

Executed October 1848.

Note.

AREA OF PREMISES 11560 SQUARE FEET,
Depth at Junction 4 feet 6 inches,
Inclination 1½ inches in 10 feet,
There are no Water Closets, – the overflow Water from the Cesspools under the Privies is conveyed away by the Pipes.
Water is laid on to the Houses, but not to the Privies.



Standidge & Co Litho. Old Jewry.

suming of course a supply of water, pipes of good form and material, properly laid, and with fair usage. Mr. Lovick.

You have had experience of blocks of houses where tubular drains have been laid down ?—I have.

You were engaged in the Cloisters of Westminster Abbey, on a block of houses, in laying down a set of tubular drains in the place where epidemic fever had broken out, and where it was supposed to have been caused or aggravated to its fatal extent by an accumulated quantity of decomposing cesspool matter underneath the foundations of the houses? —Yes. I was engaged under the direction of the Consulting Engineer to the Commission, Mr. Austin, upon this work. There were 15 houses in two blocks; each block was separately drained by one main pipe 9 inches in diameter, this being the largest size used, the sizes gradually decreasing to 4 and 3 inches for the minor branches.

How many loads of decomposing matter were taken from the drains of these 15 houses?—Upwards of 400 loads from the drains and sewers serving the 15 houses, and 120 loads from the cesspools, or upwards of 500 loads in all.

To what extent were the drains choked up?—Many were three parts full, some even more.

What was the area of evaporating surface of the drain or sewer and cesspools connected with this block of houses ? Did you not put down a system of tubular house-drains after abolishing the cesspools there?—The area of evaporating surface of the sewers connected with this block of houses would be about 3000 feet; of the drains and sewers 4300 feet, with the cesspools in addition 4800 feet. The cesspools were abolished, and a system of tubular house-drains substituted.

What was the size of the old house-drains, and the new house-drains substituted for them ?—The smallest observed house-drain was 9 inches square, the largest 2 feet in diameter, the house-drain substituted for them 4 inches in diameter.

What were the sectional areas, and sectional areas of friction, of the old house-drains and the new ?—The sectional areas are, of the 9-inch square drain 81 inches; the 2-foot circular old drain 453 inches; of the new 4-inch pipe 12½ inches; or the smallest drain would be 6½ times, the largest 36 times greater than the new drain substituted for them. The frictional line, or interior perimeter of each drain, is 36 inches for the 9-inch drain, 75 inches for the 2-foot drain, 12½ inches for the 4-inch pipe ; or the smallest old drain three times, the largest six times greater in this respect than the 4-inch pipe.

How long have the latter been now in action ?—14 months.

Has the working of these new tubular drains been carefully examined ? —Yes. In a Report made in June last on this block by Mr. Austin and myself, we state, "The delay has afforded us the satisfaction of reporting at the same time the complete success which has attended this work. The Dean of Westminster gave special instructions to the Clerk of the Works, resident in the Abbey precincts, to examine and report the condition of the drainage weekly; and not a single case of complaint has occurred during the whole period, except from an inconvenience which arose from the want of a connection to a water-closet not known of at the time, and therefore not provided for. One

Mr. Lovick. of the 4-inch branches has recently been opened to make this connection, and it was found as perfectly clean as when first laid down." The Dean of Westminster, in a letter on the state of this drainage, says, "I beg to report to the Commissioners that the success of the entire new pipe-drainage laid down in St. Peter's College during the last 12 months has been complete. The Clerk of the Works has examined every water-closet once a-week, and entered his written report in a book laid every Wednesday before the Dean and Chapter, and not one case of failure or imperfect working has occurred. I consider this experiment on drainage and sewage of about 15 houses to afford a triumphant proof of the efficacy of draining by pipes, and of the facility of dispensing entirely with cesspools and brick sewers." And up to this time they have acted, and continue to act, perfectly.

You made a joint Report with Mr. Austin upon this block of houses; will you state the results of that Report?—Yes. The old and the new systems are shown upon the two plans accompanying this Report. These will give some idea of their relative magnitude and construction. At the outlet the main sewer in the old system was 4 feet high by 3 feet 6 inches wide, varying in width to 6 and 7 feet, and in height in one part to 17 feet. Under the school the soil stood 9 feet deep. In the new drainage substituted there are two 9-inch stoneware mains, the united sectional area of which is but 1-16th of the area of the smallest part of the old sewer, and not more than one-half the area of the average of the single old house-drains. We state, "The secondary pipes are of 6 inches diameter, and the branches of 4 and 3 inches; 4-inch pipes were, however, used in many parts where 3-inch would have amply sufficed for all the requirements of the drainage, from an apprehension that the irregularity of the pipes would tend to create a certain amount of obstruction. The utmost pains were taken to secure the very best materials, and a great number of imperfect pipes were rejected and removed from the ground. The very best, however, were far from what they should have been; and we regret to say that now, a twelvemonth later, the manufacture appears not in the least degree to have advanced in quality; on the contrary, it would seem that the great increase of demand has been met by slovenliness and overhaste in execution, instead of by the application of machinery and improved appliances to the manufacture. This new drainage conveys the refuse and rain water from 15 houses, the Westminster School buildings, the Chapter-house and Cloisters of the Abbey, Little Dean's-yard, &c., comprising an area of about 2 acres. There is a total length of drain of upwards of 3000 feet. The cubical capacity of the interior of the *whole* of the new main and branch drainage is about 1-32nd part of the cubical capacity of the interior of the old sewers; or the capacity of *a portion of the old system* is 32 times the capacity of the *whole of the new system*, exclusive of the old house-drains and cesspools, or the capacity of the old sewers is equal to a depth of water of more than 2 inches on the whole surface drained of about 87,120 square feet, or 2 acres; or they would have retained a rain-fall of this depth on the whole area. The total cost of emptying the old sewer and cesspools (which was done without the slightest annoyance) amounts to 70*l.* 6*s.* 6½*d.*, which, including the extra labour of clearing the new drain, is at the rate of 2*s.* 8½*d.* per cubic yard. A flushing apparatus

was fixed to one of the main lines; this is frequently used, but the water discharged bears no evidence of any tendency to deposit in the drain and the other line which there is no opportunity of flushing is equally clear. We have not experienced, since the completion of this work, one of those extraordinary storms which occur only at intervals of years; but the result of very heavy falls of rain, which we have experienced on more than one occasion, is sufficient security on this point. At no time has either main been half charged; proving beyond a question, from the quantities discharged, that, with the increased run from the pressure in the mains when flowing full, they would be of ample capacity to avoid flooding from the greatest storm of rain hitherto recorded. Although a great number of cases of combined back drainage have already been applied for, and granted, this is the only case of any extent which has as yet been entirely laid under the superintendence of the officers of the Commission, and thus security afforded that the house branches were correctly laid, and the inlets properly protected. We fear that, had it not been so, we should not have had so satisfactory a report to make of its working; for, with the multitude of connections belonging to this drainage, it is scarcely probable but that some obstructions would have taken place in them before this, had not this point been strictly attended to; and there is every reason to fear that, unless the same security is invariably adopted, the drainage never can work satisfactorily. We call attention to this case, however, as a favourable specimen of tubular drainage only so far as the materials would allow, and not by any means as we would desire to see it either as to workmanship or cost. There are many imperfections in the pipes themselves, in the curves, in the junctions, and in the inlets; there are many 4 and 3 inch pipes used where 3 and 2 inch would have been better, if better materials had been at command; and there were many additions thus made to the already extravagant price of the pipes. Our only hope of a better result in this respect is in the special attention of the committee appointed to investigate this branch of the subject." The working of this system, as appears by the Dean's Report, and as I am informed by others, and from my own observation, has been completely successful. The smells, which were very prevalent under the old system, have not been experienced under the new, and I am informed that during the past year, a year of great mortality, this place has been remarkably exempt from sickness.

Mr. Lovick.

Does this experiment leave any doubt on the mind of yourself, and of other officers, that under a tubular system of drainage, properly laid down, there would be no decomposing refuse remaining under the houses?—It does not; nor in that, I believe, of others with whom I have conversed. There were many sceptics at the time who have now become converts to the system from seeing its successful action.

In the case of the block of houses in Earl-street, was not the drainage upon the old system from the back to the front of the house?—Yes; from the back to the front of the house.

Now, if instead of being so drained it had been drained from the back by earthenware tubular pipes, what would be the decrease in the sectional area of friction by draining them at the back; what would be the gain in fall from each house as compared with the old system and the present system?—The decrease in the frictional area would be

Mr. Lovick. five-sixths; the gain in fall, by draining at the backs of the houses instead of through each house, would be in the main line one-half, in the house drains three-fourths.

It follows then, does it not, that if the house-drains keep themselves clear and the sub-mains also, with the increased force gained by junctions at the proper inclinations, the mains also would keep themselves clear by the ordinary supply of their own water even in dry weather, and that there is no need whatever under such a system for additional supplies of water either for flushing or for keeping the drains clear of deposit?—In a system of house-drainage properly proportioned and laid at a due inclination, if the single house-drains, the branches and sub-mains, with the ordinary supply of water, keep themselves clear in dry weather by the continual concentration and acceleration of the flow, it follows that by preserving a due proportion in the sizes to the flow and in the inclinations of the mains, and with the increased force gained by proper junctions, the mains would keep themselves clear under similar circumstances, and that in such a system of house-drainage no additional supplies of water would be requisite for that purpose.

Under this system, and in this particular block of houses, supposing it were back-drained with tubular drains, what would be the greatest length of time that any decomposing matter discharged through the house-drains would remain beneath the site until removed into the trunk-main? what is the ordinary rate of discharge from any given point per hour?—I believe it may be safely estimated that, with the inclinations at command, the sewage would be removed from the extremity of the district, in the system described, into the main-trunk at this flow in a period not exceeding 15 minutes. The rate of discharge along this line at the period named would not, I think, be less than three miles per hour; but this would be subject to infinite variations as the pipes were more or less full, or subjected to the influence of pressure.

On the whole, then, it appears from these experiments to be within the power to have all the house refuse of the metropolis constantly removed at a rate of not less than three miles per hour?—Yes, with similar inclinations, and under like conditions; but with many of the present outlets this, of course, is not possible.

What is the expense per house of back drainage, and what would it have been if tubular drains had been carried through each house separately?—The expense per house in this locality of tubular back drainage, including the closet-pan, &c., would be about 4*l.* 8*s.*, of tubular separate drainage from the back to the front of each house about 8*l.*, or nearly double.

What would be the proportional increase of the sectional area of friction?—The increase in the area of friction of the separate drainage *through* the house over the combined drainage at the back would be *two-fifths;* but the area of frictional surface opposed to the flow would vary with the flow.

What would it have been if the houses had been drained by the old system?—The increase in the area of friction, or interior surface area, of the existing system of large brick sewers through each street, with separate large brick drains through each house, over the combined small tubular drainage at the back, would be five-sixths.

What would be the annual expense of the proposed new branch main sewer as compared with the annual expense of the old sewer?—I do not apprehend that there would be any, so-called, annual expense connected with new sewerage works, if properly formed in the first instance. The annual expense or cost upon the present brick sewers in this locality, if kept cleansed by flushing, would probably be about 36*l.*

What would be the expense of carrying the distributary water apparatus to the backs of the houses, on a constant system of supply?—2*l.* 8*s.*

At what would you estimate the extra expense of butts and cisterns for putting down the water-supply *de novo* on the intermittent system in this district?—The cost of providing adequate slate cisterns with the present supplies would be in this locality not less than 3*l.*

What is the proportion of the expense incurred in earthwork, simply in house-drains and others?—This will vary in localities, and according to the system pursued, and the depth at which the drains are required to be laid. The proportion of expense to the total cost would be in this locality, under the existing system, nearly one-third; under the separate tubular system, between one-half and one-third; under the combined back tubular system, nearly one-half.

Supposing, as it has frequently been considered necessary that the water-pipes should not be laid at a less depth than 3½ or 4 feet for the sake of coolness, what would be the advantage of laying the drainage and water-supply pipes together at the back? What would be the gain by the combination, or what the loss by the separation of these works? —The advantage of laying down the water-pipes and the drainage together at the back would be the saving of earthwork to the depth at which the pipes were laid, and of the paving and walls disturbed. Supposing the drains laid to a depth of 8 feet, and the water-pipes to a depth of 4 feet, the gain in saving of expense would be upwards of one-fourth on the water-supply, and nearly one-eighth on the combined works; and there is the further gain in the combination of works by one superintendence of the whole, instead of a double superintendence, which would be the case in a separation of works; and there is freedom from the annoyance of two disturbances of the premises, almost inseparable from the independent works.

Second Examination.

You were directed to examine the latest Report (1846) made to the Old Westminster District Sewer Commission under the Westminster Commission as to the means of improving the drainage of courts made shortly before the appointment of the Consolidated Commission?—Yes.

State the sizes of drains there contemplated, and what sized sewer? —The Report states that "three sizes of sewers should be used for that purpose, as represented by the sections numbered 1, 2, and 3. The first is intended for courts from 300 to 450 feet long, the second from 150 to 300 feet long, and the third for places 150 feet and less in length." They are egg-shaped in section. The sizes are 1 foot 9 inches by 3 feet 3 inches; 1 foot 6 inches by 2 feet 9 inches; 1 foot 3 inches by 2 feet 3 inches. The house-drains were of pipes 6 inches in diameter.

Mr. Lovick,

What was the common practice before the period of the publication of this Report?—The common practice prior to this Report was to construct large brick sewers adequate for the drainage of large areas, 5 feet 6 inches high by 2 feet 6 inches in width, with upright sides, curved top, and with a slightly-curved invert. The house-drains were either square or circular, 12 and 9 inches in width or in diameter, formed of brick and stone: 9 inches was the smallest size permitted to be used.

What would have been the expense per house upon that (the old) system?—About 11*l.* 5*s.*

What would be the rate of expense per house upon the improved system of back drainage?—About 1*l.* 7*s.* 3*d.*

What also would have been the expense of the system proposed in 1846, and the proportionate cost of the other systems?—About 5*l.* 4*s.*; or this system would be four times, and the old system eight times greater cost than the improved system of back drainage. The adjuncts of closets and sinks are excluded in these estimates, so that they might rest upon the system in regard only to the drains and sewers, but the proportions would be but slightly affected by their addition.

Give a comparative view as to the relative proportions, the economy, and the efficiency of these systems, viz., of the old system, of the system proposed in 1846, and of the new system of improvement by back drainage, in pursuance of the principles deduced by the investigations of the Metropolitan Sanitary Commission?—The diagrams handed in illustrate the comparative proportions of the three systems, and will elucidate their further description; taking the three systems in their several relations to each other:—

	On the		
	Old System. / Improved System of 1846.	Old System. / Improved System of 1849.	Improved System of 1846. / Improved System of 1849.
The lengths are as . . .	1 to 1	$2\frac{1}{4}$ to 1	$2\frac{1}{4}$ to 1
The inclinations of main sewers are as	. .	. .	2 to 1 nearly
The inclinations of house-drains are as	. .	. .	1 to 10
The sectional areas of mains are as	$2\frac{1}{2}$ to 1	30 to 1	$11\frac{1}{2}$ to 1
The sectional area of the single house-drain is as .	$2\frac{1}{4}$ to 1	10 to 1	4 to 1
The capacity (cubical) of whole system is as . .	$2\frac{1}{2}$ to 1	37 to 1	$14\frac{3}{4}$ to 1
The cost is as	2 to 1	8 to 1	$3\frac{3}{4}$ to 1

Thus, in the system of 1846, the sectional area of the main is $11\frac{1}{2}$ times greater than the sectional areas of the mains according to the most improved practice, and its cubical capacity $14\frac{3}{4}$ times greater; the cost of the system being $3\frac{3}{4}$ times greater. The system of 1846 would form a reservoir for a rainfall of 1 inch in depth on the whole area drained. In the old practice the sectional area of the main is 30 times, its capacity 37 times, greater than the new; and the cost 8 times greater. The three systems would retain a rainfall on the area drained of $2\frac{1}{2}$ inches, 1 inch, and one-fifteenth of an inch respectively. Thus the

economy of back-drainage, as compared with the separate system of a centre sewer through the court, with drains from and through each house, would be— Mr. Lovick.

	On the Old System.	On the Improved System of 1846.
In the length	$2\frac{1}{4}$ times	$2\frac{1}{4}$ times
Inclination of main sewer . .	. .	2 ,,
Inclination of house-drains . .	. .	10 ,,
Area of mains	30 times	$11\frac{1}{2}$,,
Area of house-drains	10 ,,	4 ,,
Capacities	37 ,,	$14\frac{3}{4}$,,
Cost	8 ,,	$3\frac{3}{4}$,,

Or four similar localities might be drained on the new system for the cost of one on the improved system of 1846, or eight for the cost of one on the old system.

State the comparative advantages of the back over the old and improved systems in regard to the acceleration of the flow, and the relative proportions of the flow in the two systems; and to the relief from stagnant refuse under the houses, and from the percolations into the strata?—The sewage in the new system has to move through less than one-half the distance than in either of the other systems, in a more direct course, with far greater inclinations, in contact with smoother surfaces, concentrated in smaller drains, and with curvatures at the junctions opposed to the entries at right angles in the other systems; thus it will be discharged in a proportionately less period. Experiments would be required to ascertain the precise effect of these improvements, but a moderate estimate would give the discharge from the houses on the new system in one-fourth the time of its discharge through the system of 1846; or the sewage in the one system would remain four times longer *under* or in the *vicinity* of the houses than in the other. In the old, porous, sieve-like system the whole of the sewage *would not* be discharged or flow uninterruptedly to its outlet; but the more liquid portions of the flow would percolate through the joints of the brickwork, be absorbed by the surrounding strata, and sap the foundations of houses, rendering them damp and unhealthy; and would frequently contaminate wells, and would deposit the more solid and offensive portions which remain *under* the sites of the houses, frequently generating disease, until removed by breaking up the drain. So that there can be no estimate of the period of the discharge of the *whole* flow in this system, as this is an impossible occurrence.

Of course the periodic cleansing of the old system would show a still larger economy in favour of the tubular back-drainage system?—The economy *in cost* of the tubular back-drainage system would be greater if the cost of the necessary periodic cleansing of this, the old, system was taken into account, for in this system accumulations would

Mr. Lovick. be forming almost from the first hour of its use, from the vast disproportion of the area to the flow; from the necessary roughness, irregularity of material, and formation; from the largely increased space through which the sewage has to pass; and from the diffusion of the flow over so many (in this case sixty-six) *separate* channels besides the main; whereas in the back system *two channels* concentrate the whole, accelerate it, and thus prevent accumulations.

In the drainage through each house, would there not be danger from the emissions of effluvia *in* the house, which would not be possible under the system where the drainage was carried at the back, at the farthest distance from the house? Is not there in the back system less disturbance of the floors of houses and of the public streets? Give a synopsis of the two systems?—In the old system there would not be any security from annoyance, or even positive danger, from its favouring *to the utmost* the escape *in* and diffusion *through* the house of the deleterious effluvia, which, sooner or later, will be emitted, but which, by the system of back-drainage, even if loaded with all the old defects, would be largely warded off. The bulk of the drainage and the *most deleterious* portion is generated chiefly *at the backs* of the houses, and would, under the old system, be sent from thence *through* the house to the sewer *in front*, having to travel through the *greatest* possible space with the *least* possible velocity, and with the widest diffusion of the flow. In the formation of the system the disturbance of the flooring, joists, and walls of the houses, of the roadways and public streets, peculiar to this system, or of far greater amount than in the back system, to the annoyance of the inhabitants and interruption of public transit, is certainly a consideration of much weight. The system of back-drainage is in every respect the converse of this system and of all systems founded upon this principle, and is in every respect superior to them: for it receives the sewage at the *farthest* possible distance from the houses, instead of bringing it *into* and *through* them; concentrates and accelerates the flow in a few channels, instead of diffusing it over many, with, in many cases, scarcely an appreciable velocity; removes all the decomposing noxious soil and drainage from the houses as it is produced instead of, as in the old system, transmitting the liquids through to the strata, and retaining the solid and more offensive portions *under* and *around* the houses; is more easily executed, with far less trouble and annoyance, and at less cost; and practice has already established it as the most efficient.

Have you not practically found that 4-inch tubular pipes work best for house-drains?—Yes.

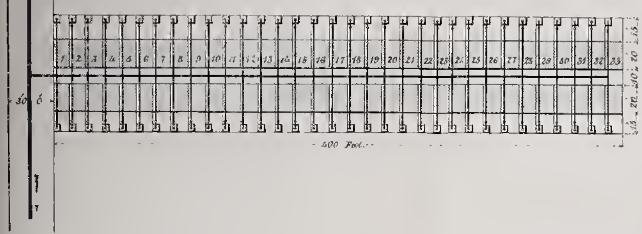
How much larger was the size of drains required for houses by the Building Act?—The *least* size required by the Building Act was *five* times larger.

Taking the block of twelve houses, drained by 4-inch pipes, which you have adduced as an example of the efficiency of small tubular back-drainage, state what would be the relative proportions of the system of drainage formerly practised in that district, and of the most approved system where the drains are carried through each house and where combined at the back?—The plan I now hand in shows the relative proportions of the systems referred to. In the old system there would be a large brick sewer through the centre of the court,

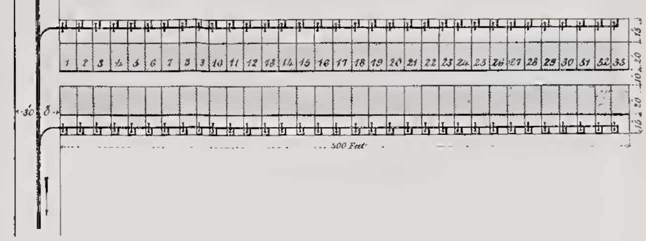
DRAINAGE OF COURTS, WESTMINSTER DISTRICT.

PLANS.

N° 1.
On the System of the Old Commission & the Improved System of 1846.



N° 2.
On the Improved System of 1849.



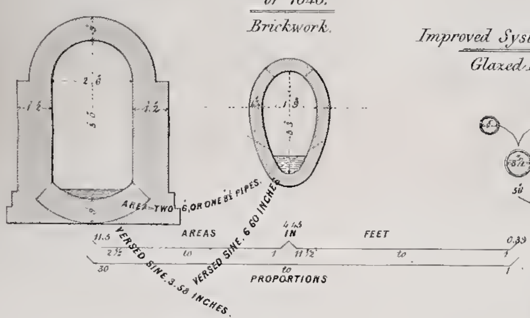
SECTIONS OF SEWERS AND DRAINS.

MAIN SEWERS.

Old System.
Brickwork.

Improved System of 1846.
Brickwork.

Improved System of 1849.
Glazed Pipes.

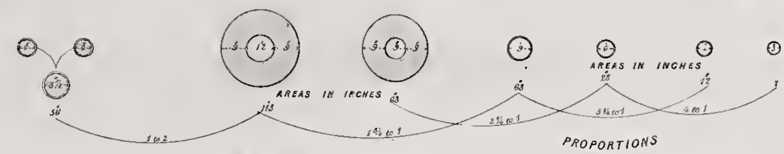


SINGLE HOUSE DRAINS.

Old System.
Brickwork.

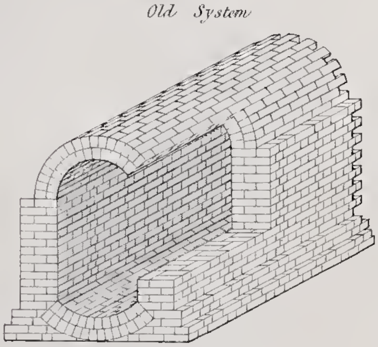
Improved System of 1846.
Pipes.

Improved System of 1849.
Glazed Pipes.

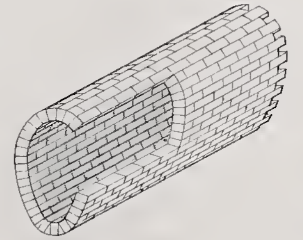


MAIN SEWERS.

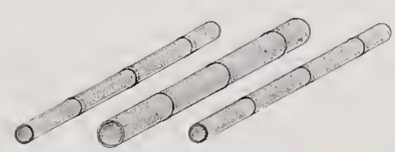
N° 1.
Old System



Improved System of 1846.

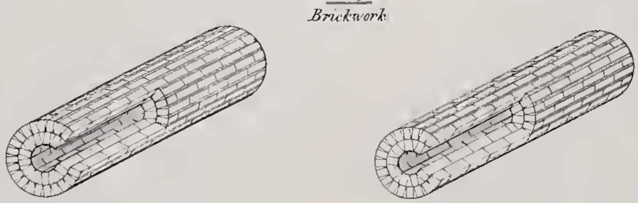


N° 2.
Improved System of 1849.
Glazed Pipes.

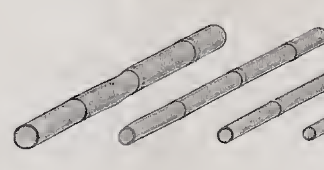


HOUSE DRAINS.

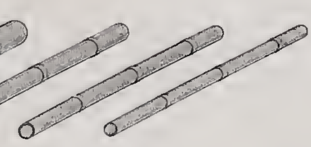
N° 1.
Old System.
Brickwork.



N° 1.
Improved System of 1846.
Pipes.



N° 2.
Improved System of 1849.
Glazed Pipes.



Scale for Sections.

Inches 0 1 2 3 4 5 10 15 Feet.

Standidge & Co. Litho. Old Jewry

with large brick drains *through* each house. In the improved system the sewers and drains would be of small stoneware pipes, whether carried through each house or combined at the backs of the houses. The collective areas of the systems would be— Mr. Lovick

The old	. . . .	15·55 feet.
The improved	(separate)	1·23
,,	(back)	0·174

Or the old would be 13 times greater than the improved separate, and 89 times greater than the improved back system, and the improved separate 7 times greater than the back system. The capacities of the systems would be—

The old	835 feet.
Improved separate	52
Back	$14\frac{1}{2}$

Or the old 16 times greater than the improved separate, and 57 times greater than the back system; and the separate between 3 and 4 times greater than the back system. The systems would retain a rain-fall on the area drained of about $4\frac{1}{2}$ inches, $\frac{1}{4}$-inch, and $\frac{1}{13}$ inch respectively.

What would be the proportionate cost per house of these systems?—The cost of the sewers and drains only, excluding the adjuncts of closets and sinks, in each system would be—

		£.	s.	d.
The old	. . . . . .	7	14	6
The improved	(separate) . .	3	1	10
,,	(back)	1	4	1

The old being two and a half times greater cost than the improved separate, and nearly seven times greater than the improved back system, and the separate nearly three times greater than the back system. With a velocity of only 3 feet per second, the extraordinary fall of rain of 2 inches depth on the area drained would be discharged by the small pipes laid at the back in twelve minutes, so that their adequacy to discharge the heaviest recorded falls of rain cannot be questioned.

Taking the water-supply to this block of houses, state the cost of the intermittent system as compared with the cost of the constant system, where the pipes are of lead and carried separately through each house?—Excluding the closet apparatus, the intermittent, 8*l.* 12*s.* 4*d.*; the constant system, 3*l.* 12*s.* 1*d.*, or less than half.

Where the pipes are of iron?—The intermittent, 6*l.* 14*s.* 8*d.*; the constant, 2*l.* 11*s.* 6*d.*, or nearly *one-third.*

Where the pipes are of stoneware?—The intermittent, 5*l.* 17*s.*; the constant, 1*l.* 18*s.* 4*d.*, or *one-third.*

What would be the proportionate expense of the intermittent and constant systems, the pipes in both cases being carried at the back? Where the pipes are of lead?—The intermittent, 6*l.* 13*s.* 10*d.*; the constant, 1*l.* 10*s.* 9*d.*

Where the pipes are of iron?—The intermittent, 5*l.* 2*s.*; the constant, 18*s.*

Where the pipes are of stoneware?—The intermittent, 4*l.* 13*s.*; the constant, 14*s.* 2*d.*

State the proportionate expense per house of works on the intermittent system, where the pipes are carried through each house and where laid

Mr. Lovick. at the backs of the houses? Where the pipes are of lead?—Where carried through each house, 8*l.* 12*s.* 4*d.*; where taken at the backs, 6*l.* 13*s.* 10*d.*

Where the pipes are of iron?—Where carried through each house, 6*l.* 14*s.* 8*d.*; where taken at the backs, 5*l.* 2*s.*

Where the pipes are of stoneware?—Where carried through each house, 5*l.* 17*s.*; where taken at the backs, 4*l.* 13*s.*

State also the proportionate expense of works for water supply on the constant system, where the pipes are carried through each house from the front to the back, and where carried at the backs of the houses?—Where the pipes are of lead, on the separate system, 3*l.* 12*s.* 1*d.*; on the combined back system, 1*l.* 10*s.* 9*d.*, or less than half.

Where the pipes are of iron?—On the separate system, 2*l.* 11*s.* 5*d.*; on the combined back system, 18*s.*, or about one-third.

Where the pipes are of stoneware?—On the separate system, 1*l.* 18*s.* 4*d.*; on the combined back system, 14*s.* 2*d.*, or nearly one-third.

What would be the proportionate cost of the earthwork and making good on the intermittent and constant systems where the pipes are carried through each house?—On the intermittent system, 1*l.* 2*s.* nearly, or, in proportion to the total cost,

Where the pipes are of lead	12·7	per cent. nearly.
,, ,, iron	16 3	,,
,, ,, stoneware	18·7	,,

Where the pipes are carried at the backs of the houses?—7*s.* 2*d.*, or, in proportion to the total cost,

Where the pipes are of lead	5·3	per cent. nearly.
,, ,, iron	7·0	,,
,, ,, stoneware	7·7	,,

What would it be on the constant system, where the pipes are carried through each house?—1*l.* 2*s.* nearly, or, in proportion to the total cost,

Where the pipes are of lead	30·4	per cent. nearly.
,, ,, iron	42·6	,,
,, ,, stoneware	57·2	,,

Where the pipes are carried at the backs of the houses?—7*s.* 2*d.*, or, in proportion to the total cost,

Where the pipes are of lead	22·4	per cent. nearly.
,, ,, iron	40·0	,,
,, ,, stoneware	50·5	,,

Supposing these works of drainage and water-supply were executed simultaneously, what would be the gain per house; or what the loss, supposing them to be carried out independently?—The gain per house from the combination of these works would be, where the drains and pipes are carried through each house, 1*l.* 2*s.*; where carried at the back, 7*s.* 2*d.*; but the proportions of saving to the total cost would vary with the materials employed.

Thus, on the old system of drainage, under the intermittent system of water-supply, where the drains and pipes are carried from a centre

main separately through each house, the saving would be, where the water-pipes used were of— Mr. Lovick

Lead	6·7	per cent. nearly.
Iron	7·5	„
Stoneware	8·0	„

Where the improved system of drainage was laid down at the backs of the houses with an intermittent supply of water, with the pipes also carried at the back in the line of the drains, the saving would be in this case, where the water-pipes were of—

Lead	4·5	per cent. nearly.
Iron	5·7	„
Stoneware	6·1	„

Where the system of water-supply is constant, dispensing entirely with the necessary adjunct of the intermittent system—the cistern, and where the drainage was upon the improved system as regards size and materials, but where the drains and pipes were laid from a centre main through each house, the saving would be, where the pipes are of—

Lead	16·3	per cent. nearly.
Iron	17·3	„
Stoneware	22·	„

But where in both cases the drains and pipes were laid at the back, the saving on these works would be, where the pipes are of—

Lead	13·1	per cent. nearly.
Iron	17·	„
Stoneware	18·7	„

The closets will be an additional expense of 14*s.* on the new system; of 2*l.* 4*s.* on the old system.

You were directed to prepare tables showing these results. Give them in?—I beg to hand in the following tables, which will give what you require:—

No. 1.—Of Water Supply and Drainage-works executed by independent authorities.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Water supply .	8 12 $4\frac{1}{4}$	6 14 $8\frac{1}{4}$	5 17 $0\frac{1}{2}$	6 13 10	5 2 0	4 13 0	3 12 $1\frac{3}{4}$	2 11 6	1 18 4	1 10 9	0 18 $0\frac{1}{2}$	0 14 $2\frac{1}{2}$
Sewerage and Drainage .	7 14 6	7 14 6	7 14 6	1 4 1	1 4 1	1 4 1	3 1 $10\frac{1}{2}$	3 1 $10\frac{1}{2}$	3 1 $10\frac{1}{4}$	1 4 1	1 4 1	1 4 1
Total . .	16 6 $10\frac{1}{4}$	14 9 $2\frac{1}{4}$	13 11 $6\frac{1}{2}$	7 17 11	6 6 1	5 17 1	6 14 0	5 13 4	5 0 2	2 14 $9\frac{1}{2}$	2 2 $1\frac{1}{2}$	1 18 $3\frac{1}{2}$

Note to this and the following Tables, Nos. 2, 3, 4, 5, 6, 7.—With the intermittent separate system of water supply the separate sewerage on the old system is placed. With the constant separate system of water supply the separate sewerage on the new system is placed. The improved back system of drainage is placed with the back system of water supply in both the intermittent and constant systems. In the first and seventh columns, under the head "Lead," the iron mains for the separate system under both modes, the constant and intermittent, are placed. The various description of pipes apply only to the water supply; two kinds of materials only being used for the drainage—brick and stoneware. And in these, as in the foregoing estimates, the closet apparatus is excluded.

No. 2.—Of Water Supply and Drainage-works executed by one authority.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Water supply .	7 10 5	5 12 9	4 15 1	6 6 $7\frac{1}{2}$	4 14 $9\frac{1}{2}$	4 5 $9\frac{1}{2}$	2 10 2	1 9 6	0 16 $4\frac{1}{2}$	1 3 6	0 10 10	0 7 0
Sewerage and Drainage .	7 14 6	7 14 6	7 14 6	1 4 1	1 4 1	1 4 1	3 1 $10\frac{1}{2}$	3 1 $10\frac{1}{2}$	3 1 $10\frac{1}{2}$	1 4 1	1 4 1	1 4 1
Total . .	15 4 11	13 7 3	12 9 7	7 10 8	5 18 10	5 9 $10\frac{1}{2}$	5 12 $0\frac{1}{2}$	4 11 $4\frac{1}{2}$	3 18 3	2 7 7	1 14 11	1 11 1

No. 3.—Of saving in the combined Execution of Works.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Works executed by independent authorities .	16 6 10¼	14 9 2¼	13 11 6¼	7 17 11	6 6 1	5 17 1	6 14 0	5 13 4	5 0 2¼	2 14 9½	2 2 1½	1 18 3½
Works executed by one authority	15 4 11	13 7 3	12 9 7	7 10 8½	5 18 10½	5 9 10½	5 12 0½	4 11 4½	3 18 3	2 7 7	1 14 11	1 11 1
Saving from combination of works, or cost of earthwork, making good the paving, flooring, &c.	1 1 11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½	1 1 11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½
Ditto, ditto, per cent. .	6·7	7·5	8·0	4·5	5·7	6·1	16·3	17·3	22·0	13·1	17·0	18·7

No. 4.—Of the proportionate Cost of Earthwork, making good the Paving, Flooring, &c., to the Water Supply.

Per House.	INTERMITTENT.						CONSTANT.					
	Separate.			Back.			Separate.			Back.		
	Water Pipes of						Water Pipes of					
	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.	£. s. d.
Water supply, including earthworks, &c. . . .	8 12 4	6 14 8¼	5 17 0½	6 13 10	5 2 0	4 13 0	3 12 1	2 11 5	1 18 4	1 10 8½	0 18 0½	0 14 2½
Earthwork, making good paving, flooring, &c. .	1 1·11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½	1 1 11¼	1 1 11¼	1 1 11¼	0 7 2½	0 7 2½	0 7 2½
Percentage, nearly, of earthwork, &c., to total cost.	12·7	16·3	18·7	5·3	7·0	7·7	30·4	42·6	57·2	23·4	40·0	50·5

Mr. Lovick.

No. 5.—Of the proportionate Cost of Earthwork, making good the Paving, Flooring, &c., to the Sewerage and Drainage.

Per House.	Old System of large Brick Sewers and Drains.	New Tubular System. Where carried through each House.	New Tubular System. Where carried at the Backs of the Houses.
	£. s. d.	£. s. d.	£. s. d.
Total cost, including earthwork, making good, &c.	7 14 6	3 1 10	1 4 1
Cost of earthwork, making good, &c.	1 17 1	1 13 4	0 14 9
Percentage of earthwork to total cost	24	54	61¼

No. 6.—Percentages and Approximate Proportions of Cost of the Constant on the Cost of the Intermittent System of Water Supply.

Separate.			Back.		
Where the Pipes are of—					
Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
41·8 or $\frac{4}{10}$	38·2 or $\frac{4}{10}$	32·7 or $\frac{1}{3}$	22·9 or $\frac{1}{4}$	17·6 or $\frac{1}{6}$	15·2 or $\frac{1}{7}$

No. 7.—Percentages and Approximate Proportions of Cost of the Back on the Cost of the Separate System of Water Supply.

Intermittent.			Constant.		
Where the Pipes are of—					
Lead.	Iron.	Stoneware.	Lead.	Iron.	Stoneware.
77·6 or $\frac{3}{4}$	75·7 or $\frac{3}{4}$	79·4 or $\frac{8}{10}$	42·6 or $\frac{4}{10}$	35·0 or $\frac{1}{3}$	37·0 or $\frac{1}{3}$

Third Examination.

You were directed to make experiments in cleansing by water by means of the hose and jet; will you state at what place you first carried them on?—Yes; the experiments were first carried on in Charles-street, Old and New Compton streets, Church-Passage, Dean-street, and Greek-street, Soho; subsequently in Church-lane, and four courts in St. Giles's.

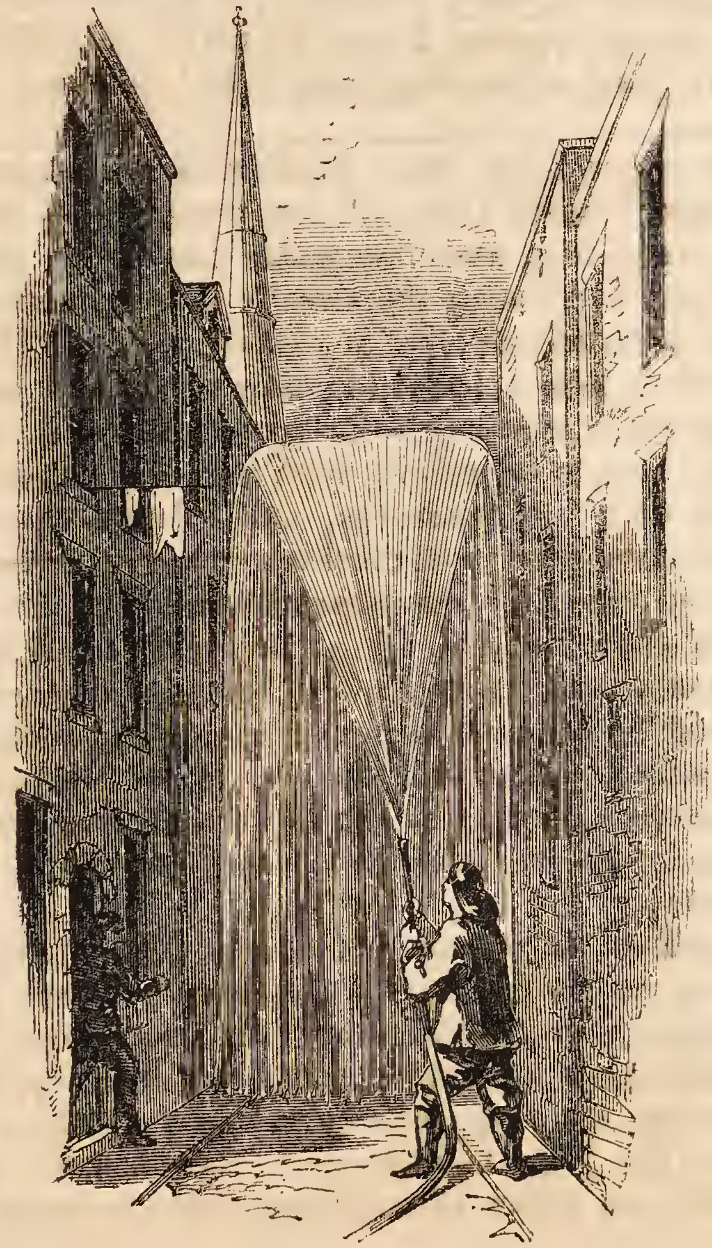
Were you not able not only to cleanse the pavements by this means, but also to cleanse the walls from urine stains and other filth?—Yes.

You were directed to prepare a sketch to show how the same plan can be carried out in courts and alleys. Give it in?—The sketches which I now hand in show the jet in operation. No. 1, is an illustration of the mode of surface-cleansing; No. 2, of the method of using the jet as a shower in close courts and alleys.

Mr. Lovick.

No. 1.

No. 2.



Mr. Lovick. State the quantity of water used each time, and the expense ?—The quantity of water used was nearly one gallon per square yard ; the cost was at the rate of 9*d.* per 1000 yards, taking the cost of water on Mr. Wicksteed's estimate.

Then it is clear from your Reports that, in respect to economy of time and of money, it is superior and is more efficacious in removing surface-evaporating matter or filth than any other method ?—In a Report to the Commissioners of Sewers I have estimated that the cost of the ordinary scavengering would be nearly double the cost of cleansing by the jet, and the jet has been shown to be far more efficacious in removing evaporating matter and filth.

You were directed to prepare an estimate of street-cleansing by these modes, as applicable to two large thoroughfares ?—Yes ; I prepared estimates of the cost of cleansing by the jet in the Strand and High-street, Borough.

Within what time and at what expense did you estimate this could be performed, apart from the cost of the water used ?—The estimates were framed on the supposition that the work should be performed in one hour. In the Strand the daily cleansing of the carriage-way would have cost 3*d.* per house per week ; in the Borough, $2\frac{3}{4}$*d.* per house per week. But this rate is for wide streets with a large amount of traffic, on data from experiments with very low pressures, and is greatly in excess of the ordinary description of works, and would by no means therefore be a criterion of the average expense.

What is the quantity of water required per square yard of pavement? The quantity of water required I have found to be rather less than one gallon per square yard of carriage-way ; but this was with extremely low pressures.

Were not the experiments often made under what were considered other disadvantages besides those of low pressures ?—They were ; the pressures being very low, and the water having to pass through a great length of hose, decreasing the already limited power.

With a higher pressure may we not safely estimate that they might be performed with a less amount of water and in a shorter time ?—Yes ; I had occasion to compare some experiments in cleansing by the jet made by Mr. Lee, of Sheffield, with very high pressures, with my own experiments with low pressures, and I found that he could perform the work in less than one-third the time, at one-third the cost, and with less than one-third the expenditure of water. From this it would appear that the economy of high pressures must be very great.

What is the quantity that would have been used for the Strand for each complete cleansing ?—By the latest experiments $18\frac{1}{4}$ thousand gallons.

In a day of partial rain, when the streets are sloppy and muddy, would not the cleansing by jet be the most eligible mode of cleansing ? —The cleansing by jet on those days I consider would be by far the most eligible mode.

What was the effect in hot weather and at other periods of this new mode of cleansing as compared with the mode of cleansing by scavengering ? What was your general conclusion from these experiments as to the effect of this mode of cleansing ?—The cleansing by water produced a most perfect state of cleanliness by the removal of *all* decomposing refuse, and the jet, when directed upward in the form of spray, appeared to have the effect of a shower, the air being made much

Mr. Lovick

cooler and fresher by it. The ordinary mode of cleansing by scavengering would have failed in removing much of the refuse, all of which the jet removed, and of course could not in any other way have improved the salubrity of the atmosphere. In hot weather these effects were more marked, the jet performing, but in a far more efficient manner, the office of the watering-cart. The ordinary mode of scavengering, without possessing any of the advantages of the jet, performed the work in a most imperfect manner. The system of cleansing by water eminently combined completeness with efficiency of action.

Even where it might be desirable to use a street cleansing machine to prevent accumulations of solid dung and the like, would it not be of importance to use the jet also?—In a Report upon this subject I have stated the general conditions wherein the combination of the two would be of advantage for this purpose, but that the machine should be auxiliary to the jet, than conversely as implied, in the following passage: "The frequency of application of this system (cleansing by jet) to the cleansing of the streets would be determined by their specific requirements, some, as the main thoroughfares, requiring daily cleansing, others cleansing at longer intervals. Thoroughfares having a large amount of traffic would require cleansing at an early period of the day; from this period to the cleansing on the following day the accumulations will have been going on and the exhalations from them discharging into the atmosphere. It may be necessary to employ measures for the prevention of this condition in conjunction with the systematic operations of cleansing by water. To effect this there are two methods, by sweeping with hand labour, and cartage of the refuse; by the cleansing machine; hand labour, when compared with the cleansing machine, would appear to be the least economical in the proportion, as stated in Mr. Whitworth's evidence, of about three to one. The machine therefore would appear to be the best adapted for this purpose, and with the least interference with the traffic of the street."

What is the total quantity of water, according to your estimate, that would be required for the purpose of street washing by means of the jet?—Assuming that there are 300,000 houses in the metropolis, with an average to each house of paved carriage-way 28 square yards, of paved footway 16 square yards (on data afforded by an average district, in the absence of other certain data), the area of carriage-way would be, in round numbers, $8\frac{1}{2}$ millions, of footway $4\frac{3}{4}$ million square yards. With one gallon of water for each square yard of carriage-way (a proportion somewhat greater than I have found in practice with low pressures, and far greater than I believe would be the case with high pressures), and half a gallon for each square yard of footway, the quantity of water required for the *daily* cleansing of these areas would be nearly 11 million gallons, or $65\frac{1}{2}$ million gallons per week, or a rate per house of 218 gallons weekly, or $36\frac{1}{2}$ gallons daily. With a population of 7 to each house the rate would be nearly $5\frac{1}{4}$ gallons per diem for each inhabitant. Taking the cleansing of the streets in a ratio approximating to their specific requirements, about *one-third* daily, *one-half* twice, and the remainder *three* times per week, the quantity of water *per diem* would be 6·2 million gallons, or 20 gallons per house, or nearly 3 gallons per diem for each inhabitant. The following tables show the particulars more in detail:—

Mr. Lovick.

No. 1.—Of the Carriage-way.

Period of Cleansing per Week.	Quantities to be cleansed at each Period.	Total Quantities cleansed per Week.	Water required, in Gallons.			
			Per Week.		Per Diem.	
			For Quantities cleansed	Per House.	Per House.	Per Individual.
No.	Square yards.	Square yards.				
6	2,750,000	16,500,000	16,500,000			
3	1,000,000	3,000,000	3,000,000			
2	4,750,000	9,500,000	9,500,000			
	8,500,000	29,000,000	29,000,000	96·7	16·1	2·3

No. 2.—Of the Footway.

Period of Cleansing per Week.	Quantities to be cleansed at each Period.	Total Quantities cleansed per Week.	Water required, in Gallons.			
			Per Week.		Per Diem.	
			For Quantities cleansed.	Per House.	Per House.	Per Individual.
No.	Square yards.	Square yards.				
6	1,536,000	9,216,000	4,608,000			
3	576,000	1,728,000	864,000			
2	2,688,000	5,376,000	2,688,000			
	4,800,000	16,320,000	8,160,000	27·2	4·53	0·65 (nearly).

No. 3.—Of the Carriage and Foot Ways.

Period of Cleansing per Week.	Quantities to be cleansed at each Period.	Total Quantities cleansed per Week.	Water required, in Gallons.			
			Per Week.		Per Diem.	
			For Quantities cleansed.	Per House.	Per House.	Per Individual.
No.	Square yards.	Square yards.				
6	4,286,000	25,716,000	21,108,000			
3	1,576,000	4,728,000	3,864,000			
2	7,438,000	14,876,000	12,188,000			
	13,300,000	45,320,000	37,160,000	123·9	20·63	2·95 (nearly.)

It is stated that the quantity of water pumped into the metropolis is 50 million gallons per diem, or at the rate of 200 gallons per house?—It has been so stated.

Have you seen the estimate made by Mr. Mylne of the actual quantity of water consumed per house, taking the average of houses of different classes, and does that estimate correspond with the results of your own observations?—I have. My principal observations would refer to classes of houses (supplied by the West Middlesex Company) on an average somewhat higher than the medium between what Mr.

Mylne calls houses of the middle class and houses of the poor, having receptacles for water. These observations give an average consumption of 5·7 gallons per individual per diem. The mean of the two classes of houses in Mr. Mylne's estimate is 5·53 gallons per individual per diem, showing an accordance between them. Mr. Lovick.

What is the quantity, according to his returns, that would be used per house in the Earl-street district?—Taking the consumption as the mean of the second and third class houses in Mr. Mylne's estimate, the quantity used in the Earl-street district would be nearly 50 gallons per house per diem.

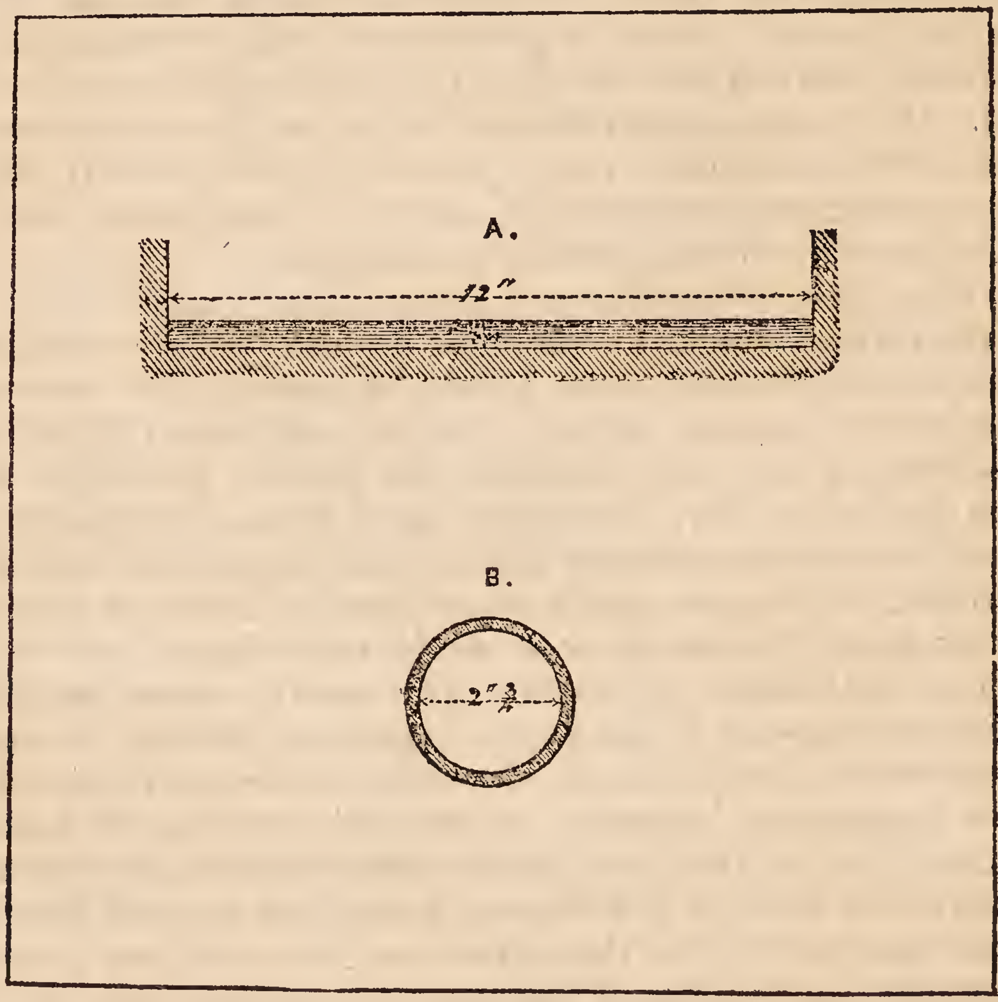
Supposing that 50 million gallons of water are at the present time supplied to the metropolis, would it not appear from the trial-works and observations that there is an amount of waste of more than one-half on the present system of intermittent water distribution?—The actual waste, from my observations, is three-fifths of the whole quantity supplied. On the supposition that the waste was in this proportion over the whole of the metropolis (and it would appear to be so), 20 million gallons would be the quantity used, and 30 million gallons the quantity wasted, of the 50 millions stated to be supplied.

Then from these trial-works and observations it appears that more is wasted than would suffice for the most profuse system of cleansing?—The system of cleansing must indeed be profuse that would require anything like the quantity wasted; but the application of the waste to surface-cleansing will best illustrate this point. The daily waste, or waste on the water day, in the Earl-street district is 187,000 gallons. This would cleanse the whole of the carriage-way on the area five and a half times, or the one day's waste would cleanse it nearly every day for six days in the week, or it would once cleanse a street 30 feet in width by 10½ miles in length. The weekly waste would cleanse *daily* the carriage-way of three such localities. Taking the same proportion of waste as applicable to the whole of the metropolis, the daily waste on the quantity stated to be supplied would be 30 million gallons. One-third of this waste would suffice for the daily cleansing of the whole of the carriage and footway paving, on the data before given, and about one-fifth where the periods of cleansing are proportioned to the specific requirements of localities; but the frequency of cleansing would considerably decrease the proportionate expenditure of water, and would reduce these proportions, which are founded upon the experimental first cleansing of streets.

Supposing you provided for a general supply of water, including general street-cleansing by use of the jet in summer, and presuming a general substitution of the soil-pan apparatus for cesspools, do you think it probable that the entire demand would be for more than two-thirds the quantity of water now stated to be supplied to the metropolis?—The quantity of water stated to be supplied is 50 million gallons per diem, at the rate of 200 gallons per house: this would indicate a supply to 250,000 houses. Taking the number of houses in the metropolis at 300,000, or 50,000 beyond the number which appears to be supplied, and a supply of 76 gallons per diem to each, as this appears to be the rate of consumption in the higher-class houses, we get the rate per diem of 22,800,000 gallons. For street-cleansing we have 36⅓ gallons per house per diem, or a gross rate per diem of 10,900,000 gallons, or for the domestic supply and for street-cleansing 33¾ millions

Mr. Lovick. nearly. Thus, with an average supply of 76 gallons per house per diem, the 300,000 houses would consume less than one-half the present stated supply to 250,000 houses, and with the addition of the quantity required for street-cleansing, about two-thirds; but the supply for manufactories, which I presume is included in the stated quantity, would require to be known, in order to see what is absolutely due to the house (or domestic) supply, and so to estimate its influence on these proportions.

State whether, from the trial-works and observations, it does not appear to be possible, by improvements in the construction of the pipes, to diminish the area of friction and increase the force of water, and thus reduce the necessity of additional supply?—The annexed diagrams



will illustrate the decrease in the area of friction with increase of height, and consequent gain of power by the adoption of pipes. Thus let A represent a square 12-inch drain, with a flow of water through it ½-inch in depth; the area of the flow will be 6 inches, the frictional surface in contact with it 13 inches. Introduce this flow into a pipe of equivalent sectional area, B, the height is increased nearly *six-fold*, whilst the frictional surface of contact is reduced *one-third.* But the water, *in rising* in the pipe, moves with an accelerated velocity: it would, therefore, occupy but a portion of the area of the pipe. Thus, in the case supposed, there might be a reduction in the size of the pipe, or a larger flow might be sent through it. In common drains of the kind in the example, the friction is greatly increased by the defective materials and irregularity of form. Mr. Roe has found the velocity in glazed pipes to be one-third greater than in brick-made drains (*vide* Evidence in First Report of Metropolitan Sanitary Commissioners). The common description of pipes are much superior in this respect; and, with the extension of improvements, they would possess still

further advantages. It is clear, therefore, that power is gained by the introduction of the tube; and as smoothness of surface and regularity of form lessen the friction, you further increase the gain by attention to these points; and it has been found where tubes have been introduced, even in cases where the supply of water has been scanty, that they have acted successfully. With the present supply of water properly distributed, in conjunction with a proper tubular system of drainage, you may no doubt greatly reduce the necessity for an additional supply for drainage purposes. **Mr. Lovick.**

Supposing the soil-water which is delivered be required to be pumped out in any direction, say on an average lift of 100 feet, what would have been the gain of engine-power by the reduction in the quantity of water needed by the most improved system of drainage and water-supply, as deduced from these trial-works and observations?—In the absence of information as to the quantity supplied to manufactories, there are no precise data for estimating it; but if we take the difference between the stated daily supply, 50 million gallons, and that stated as the required supply, $33\frac{3}{4}$ millions nearly—or $16\frac{1}{4}$ million gallons—the gain in engine-power, on the supposition that this quantity was raised in 12 hours, would be 683 horse-power.

Were not the earthen pipes first used very defective in construction? —Yes, they were very defective in construction, few approaching to anything like regularity of form—rough, ill glazed, and with many indentations and protuberances, which would greatly impair their efficiency.

Have you seen specimens of improved pipes, made with pressure, which give a greater regularity of flow? Does not the increased velocity amount to one-third, or one-fourth?—Yes.

With the extension of similar improvements, have you any reason to doubt that great increase in the velocity of discharge, compared with the present apparatus, might be produced, consequently reducing the need for additional supplies of water for keeping the drains clear? —Superior make and regularity of form of the pipes considerably reduce the friction, and promote greater regularity of the flow, and would accelerate it. In those specimens which I have seen, the acceleration is stated at *one-fourth*, a result obtained solely by improvements in the manufacture, by the extension of which I have no doubt but that a great increase in the velocity might be obtained.

What were the general statements as to the expense of the water-supply in several districts that were investigated?—In St. James's parish the average expense per house per annum, as returned by the occupiers of 1885 houses, was 3*l.* 0*s.* 2*d.* In St. Ann's, Soho, the average expense per house per annum, as returned by the occupiers of 1173 houses, was 1*l.* 17*s.* 5*d.* In St. George's, Southwark, the average expense per house per annum, as returned by the occupiers of 2064 houses, was 1*l.* 7*s.* 9*d.*

What was the average rate of expense for water as returned by the tenants of the 1100 houses in the Earl-street district?—The average rate of expense for water as returned by the tenants of 856 houses in this district was 34*s.* 1*d.* per house per annum.

It appears from the returns of the London and Vauxhall Company that there are some thousands of houses in their district without the means of receiving water, and that its very abundance is productive

Mr. Lovick. of evil in making the neighbourhood damp and unfit for habitation. Is the same remark applicable to other districts?—I believe it will, more or less, apply to all the districts. Although there are stringent provisions for the prevention of waste, as the Companies require proper cisterns and butts and ball-cocks to be provided, yet, from this regulation not being complied with, and from the defective working of the apparatus, either naturally or from design, waste occurs to an enormous extent, and in many situations produces the condition stated by the Southwark and Vauxhall Company as occurring so largely in their district.

You have, no doubt, observed, in cases where drainage is deficient, great dampness caused by the waste of water?—Yes, frequently. I am now in communication with an owner of property who proposes to lay on the water to several houses so soon as proper drains are provided for taking off the waste, and for which he has applied. He has stated to me that he would not lay on the water without the drains were first provided; and I have no doubt but that this consideration weighs with many landlords, as the injury arising from dampness caused by the water-supply, where drainage is deficient, is incalculable.

Have the earthenware sewer pipes which you have put down been in macadamised roads?—There have been some put down in roads of that description.

Have they had any protection from granite detritus?—Some of them have not.

And yet they have kept themselves clear?—In those cases in which the pipes have kept themselves clear there has been a good flow of water, and they are laid at a good inclination.

Does it not appear that with a good flow in the main-line if the stuff from roads was sent into it it would be carried off?—With the main-line laid at a due inclination, and with a good flow of water through it, the slop from the roads in wet weather would, I believe, be carried off; but hitherto there has not been a sufficiently large experience on this point to speak with absolute certainty.

Was it not considered desirable and practicable, nevertheless, to make shallow cesspits for the gully-shoots for roads, to prevent granite detritus from getting in?—It was, and very judiciously so, in the present arrangements and with our present experience on the subject.

But this is with a continuous fair fall; now, supposing the continuity of the fall to be interrupted by the outlet being below high-water mark, of course the matter which before was carried in suspension would be deposited?—As the power to remove matter in suspension is in proportion to the volume of water, and to the velocity with which it moves, and as this velocity increases with the increased inclination, any interruption of the fall or decrease of inclination must be attended with a proportionate loss of power, and this becomes progressive in sewers situate in districts below high-water mark, where the outlets are affected by the tide, so that where sewers pass through a district of this kind from a higher level the matter held in suspension in the flow in the higher parts is deposited as it is brought down into the lower level.

Is it not found that this detritus becomes indurated, and requires a greater force of water to remove it than that necessary to keep it in suspension?—Yes. The detritus will become so indurated as to require a very considerable force of water, and even manual labour

aided by proper implements to remove it, so that the force of water necessary to keep such matter in suspension bears but a slight proportion to the force requisite for its removal when it has once become indurated. Mr. Lovick.

In places which are below high-water mark for how many hours is the flow arrested?—This will vary in places. In some districts the flow would, on the average, be arrested for two-thirds of the day, or for 8 hours during the daily tides, or for 16 hours, taking the tides throughout the 24 hours.

Then, in consequence of the arrest of the discharge in these low-lying districts, a much larger volume of water is requisite to lift and remove the matter so deposited?—Yes. The quantity of water necessary to keep matter in suspension in lines laid at a due inclination, and, where the discharge is continuous, bears but a slight proportion to the enormous volume required to lift and remove the same matter after it has been deposited.

Supposing the additional quantity of water necessary to remove the deposited and indurated matter is to be sent in by pumping, would it not be a greater economy of pumping-power to lift the water from a lower artificial level, in order to preserve the continuity of the discharge? With a proper tubular system of house-drains and sewers, would it not be a large economy of power to pump?—If the supply of water now used for the prevention of accumulations of deposit in this district had to be pumped into the district, and if, as the question implies, an artificial outfall was to be provided, so as to ensure a proper tubular system of house-drains and sewers, or a system constantly discharging, the power requisite to pump the supply of water now used into the district for the prevention of the accumulations of deposit from the ordinary drainage in the present sewers would much exceed the power requisite to pump up the ordinary drainage from such artificial outfalls, much more would be the excess of power required were *additional* supplies of water pumped in for sewer-cleansing purposes.

You of course have had to flush the sewers in the Surrey and Kent district, and have observed there the effect of the intermittent discharges of the drainage matters which are backed up and kept within the district during high-water? In the discharge of the sewers there, is not the supernatent sewage water decanted off, leaving the matter deposited, and what are its effects?—Yes. From the drainage-matter in this district being locked in for many hours in each day, a very large proportion is deposited, and, when the outlets become free, then the liquid portion, with but a slight amount of the solid matter, is decanted off, or flows, into the Thames. And as the reservoir-sewers become full, the foul gas is expelled from them through every opening into the public thoroughfares and into the private houses. And the generation of foul gas is quickened by the stagnation of the drainage, being continually formed and continually expelled by the progressive accumulation, so that not only are mechanical difficulties created, but health is jeopardised by this arrest of the flow.

Have you estimated what would be the quantity of water required to flush away this matter?—It would be difficult to do so, as (owing to many of the collateral and parts of main sewers being below their outlets; to irregularities in them; and to the unavoidable deficiency of fall in even the best constructed lines, from much of the district being

Lovick — below high-water; and from the drainage being locked in by the tide about two-thirds of the time) it is impossible to remove much of the deposit from many of the lines. The present quantity of water, with the immense volume now procured from the Thames through the various sluices, probably at least from eight to ten times greater than the ordinary sewage-flow, is wholly inadequate to keep even many of the better class of the low-level sewers clean.

In that district it appears that there have been and are now daily presented demonstrations of the interruption of the flow of water, from the district being below high-water mark?—Yes.

In many instances are not some of the outlet sewers brought down to low-water level?—Some are brought down to within from 2 to 4 feet of low-water mark.

In respect to the pollution of the Thames water, have you seen a statement of the relative rate of flow of the tides?—Yes.

Take the case of sewer matter discharged—say at Rotherhithe—what would be the highest point up the river at which it would be safe to take the water for domestic use?—It is stated by some that the flood-tide continues for 7 miles, and the ebb for 10. Now if matter was discharged at Rotherhithe (say by the Thames Tunnel) at low-water, or the turn of the tide for flood, it would travel, supposing the whole mass to move, 7 miles up the river, or to nearly half-way between Battersea and Putney Bridge, and *above* the Counter's Creek sewer, the highest main outlet in the Westminster district of sewers, and considerably above the points from whence the Southwark and Vauxhall, and Chelsea water companies at present derive their supplies; so that, if water is required for domestic use, uncontaminated by sewage matter, it could not be taken, at least during certain periods, from any part between these points; but this is without reference to matter discharged at higher points, which at present contaminates the river far above these limits, and this is daily increasing with the extension of the town westward. For instance, the Counter's Creek sewer, which a few years since discharged but little else than land waters, and was so instanced before the committee on the Metropolis Water Supply so late as 1834, now receives a large amount of house-sewage, which is rapidly increasing from the rapid extension of buildings on this area. Upon the rates of the tides, and their proportions to each other, there are various conflicting statements, so that they can only be very approximately stated, and must be received merely as rough approximations to illustrate the principle of the tidal action.

How many loads of sewer deposit have been removed in any one week in the Surrey and Kent district? What is the total quantity of deposit removed in any one week in the whole of the metropolitan district?—It is difficult, if not impossible, to ascertain correctly the quantity removed, owing to the variety of forms of sewers and the ever-varying forms assumed by the deposit from the action of varying volumes of water; but I have had observations made on the rate of accumulation, from which I have been enabled roughly to approximate it. In one week, in the Surrey and Kent district, about 1000 yards were removed. In one week, in the whole of the Metropolitan districts, including the Surrey and Kent district, between 4000 and 5000 yards were removed; but in portions of the districts these operations were not in progress.

Does not the flow tend to form channels in the deposit, proportioned

TRANSVERSE SECTIONS OF SEWERS,

Shewing the action of the water upon the deposit.

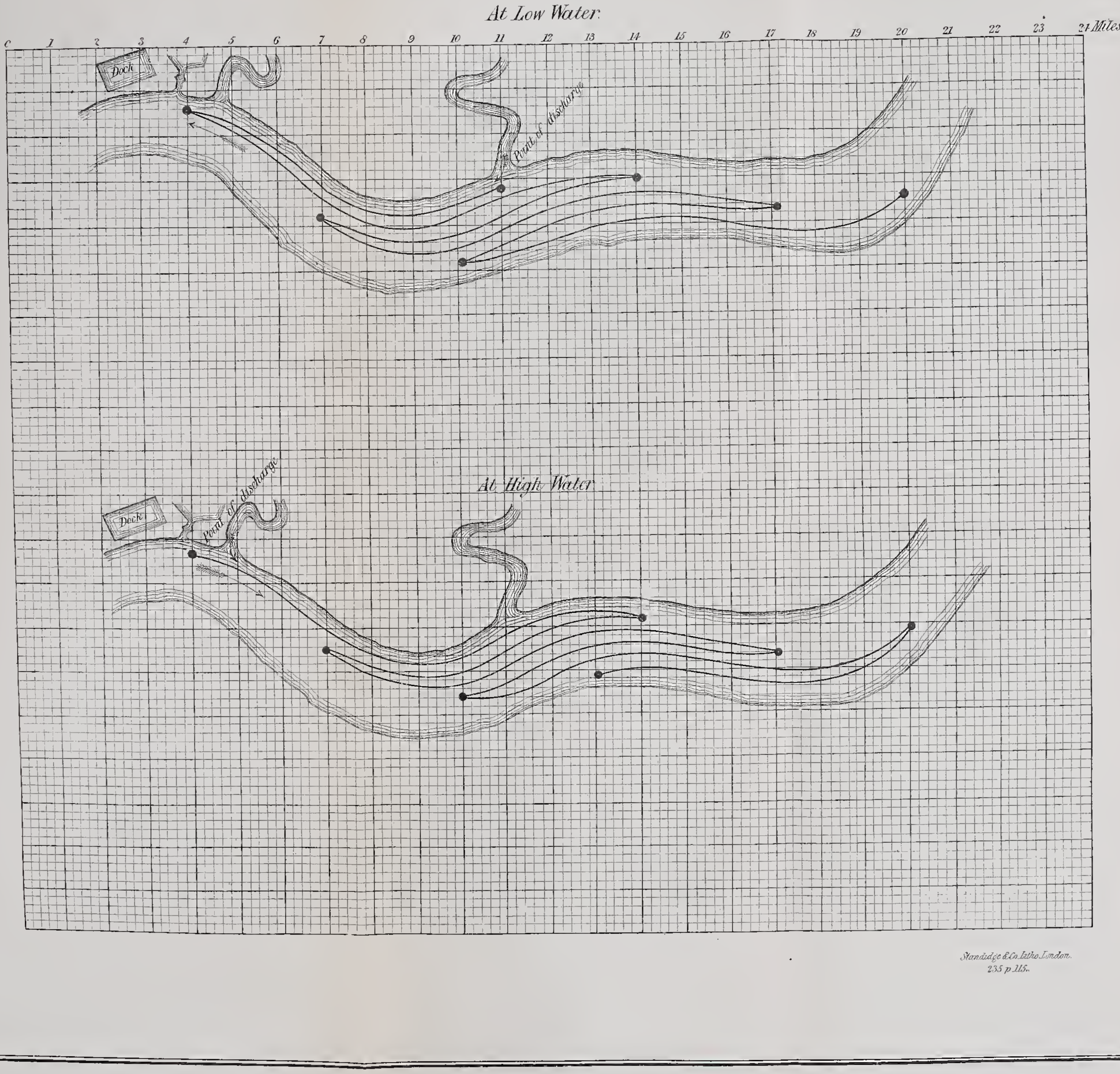
The dark portions shew the deposit,
The blue tints shew the water.

SCALE OF FEET.

Thos Lovick.

204 p. 114
Standidge & Co Litho Old Jewry

Diagrams illustrative of the flux and reflux of the Tidal Waters in the River Thames, on a float discharged at the periods of High and Low Water.



Standidge & Co. Litho. London.
235 p 115.

to its volume? Give cross-sections illustrative of this point?—Yes; the sections which I now hand in show that this is so. (*See* Plan.) Mr. Lovick.

Are not these channels frequently curved, and do they not frequently indicate the proper proportion of passage to the volume passing through them?—They do.

In the performance of your duties in the direction of flushing operations, you will have observed the points of discharge or the outlets of the main lines of sewer flushed. You were directed to observe, as far as you might have opportunity, the range of contamination of Thames water from such flushings. Describe them?—It would be difficult to except any part of the Thames within the influence of the tides from the range of contamination from the flushings of the sewers into it, or from their natural discharges; many of the main outlets being high up the river. In the Report of the Committee of the House of Commons on the Metropolis Water Supply, in 1834, an experiment to ascertain the rate of flow of the tide is recorded. A float was placed by the King's Scholars' Pond sewer at the commencement of the flood, during or near a spring-tide, which travelled nearly half a mile above Kew-Bridge; the actual distance travelled being 10½ miles in five hours and nine minutes. The King's Scholars' Pond sewer is not the highest large *main* sewer on this, the north, side of the Thames; the Ranelagh sewer, draining a larger area and receiving a very large amount of house-drainage, and the Counter's Creek sewer, being above it; but this will give some idea of the range of contamination.

You were directed to take the highest sewer and the lowest sewer outlet into the river Thames, under the jurisdiction of the Metropolitan Commission of Sewers, and, supposing the discharge of each sewer at the usual time after high water, delineate the progress or the extent of flux and reflux of the sewage, until its final exit from the populous portions of the bank of the Thames, as (say) Erith or Woolwich; or, supposing a floating body to be discharged from the sewer, mark its track of flux and reflux?—The flux and reflux of the river, in its effect upon any floating body discharged into it, may be best shown (although, for the reasons before stated, this can only be approximately done) by considering the discharge to take place at the extreme limits—of the flux in the one case, of the reflux in the other: assuming the tides to be, as they are generally stated, in the following proportions—the flux to run 7 miles, or 5 hours; the reflux 10 miles, or 7 hours; and that the whole mass moves.

The diagrams A and B will represent the discharges as affected by these two conditions.

The black lines show the flux and reflux; O the floating body at the moment of discharge; and the black dots the same body at different stages of the tides.

Take the discharge at high water, as in diagram A.

In 7 hours the float has travelled 10 miles *down* the river, in 12 hours it has returned 7 miles *up* the river, or to within 3 miles of the point of discharge. At the 31st hour it is 16 miles down the river, and has returned at the 36th hour to within 9 miles of, or is removed that distance below, the starting-point.

Take the discharge at low water, as in diagram B.

Supposing the most valuable manure were to continue to be wasted,

Mr. Lovick. at what time and at what point, by pumping, might the sewage-water of the south side of the river be discharged apparently safe: that is to say, safely from the pollution of the river or banks within the densely populated districts? At what point from the north side of the river?—The period at which the sewage might most *safely* be discharged would be at high-water, or the turn of the tide for ebb, as it would then be removed the furthest distance from the town in the shortest time; and assuming the correctness of the statement, that there are 3 miles in favour of the ebb, the sewage would in the one tide be permanently removed 3 miles below the point from which it was discharged. The discharge at low water, or the turn of the tide for flood, would require seven tides, acting over a period of 41 hours, to produce this effect, according to the proportions of the flood and ebb which have been generally given. Greenwich on the south side, and Blackwall on the north side, may be considered as the limits of the densely populated districts; but on the south side, below Greenwich, is Woolwich. The limit of density of population at the point lowest down the river, whether on the south or on the north side, should govern both sides on this question, as the point which might safely serve one side might endanger the other, if situate lower down on the opposite side, the sewage flowing from both sides into the *one main* channel. So that if the extreme point be taken, and the discharges considered as taking place at high water, the river at Blackwall would be the point for both sides; although for the south side a shorter course could be taken, which would for this side take the sewage about one mile lower down the river.

Mr. John Grant, examined.

Mr. Grant. Are you not surveyor to the Metropolitan Commissioners of Sewers?—Yes: for a considerable portion of the Surrey and Kent district.

Had you previously executed works of drainage yourself?—I had.

Have you had experience of the practical working of tubular drainage?—Yes.

From what you have seen are you convinced that these drains will keep themselves clear if on a proper inclination?—I am. Within the last few weeks I sent to know how the 4-inch drains I had put in at Exeter, twelve and eighteen months ago, had answered, and in every case I found that they had done so perfectly, notwithstanding that some of them had been put down without water supply. The parties concerned are perfectly satisfied with them.

What is the largest number of houses in one block that you have drained on the tubular system?—130 for one gentleman, but it was not convenient for him at the time to lay on water. The drains have, however, acted well, notwithstanding the risk thereby incurred.

On your appointment as surveyor under the Metropolitan Commissioners of Sewers you were directed to examine and report on the working of the earthenware tubular drains, which had been ordered by the new commission of sewers to be laid down?—I was.

Most of those works had been combined with the service of water-supply?—In most cases they had; but in some they had not.

Mr. Grant.

It will be seen that the float has been brought back five times to the point from which it was first discharged, after having travelled to the point of last coincidence 42 miles through six tides. So that the float is permanently carried, at high water, in six tides, extending over 36 hours, 9 miles below the discharging point; at low water, in seven tides, extending over 41 hours, two miles *below* it. Or to produce the effect of the discharge at high water it would require twelve tides acting over a period of nearly 66 hours, through a space of 93 miles, on the supposition, as before, that these quantities approximately represent the rates and proportions.

The outlets of the sewers are at points *intermediate* between high and low water, so that the discharges will be at various stages of the tides, carried *down* a less distance in the *reflux*, carried *up* a less distance in the flux, oscillating proportionately between the limits of the flows; but the diagrams will serve to show the general action of the tides in the simplest manner.

From these observations you are enabled to speak from the demonstrations of trials, made under varied and disadvantageous circumstances, as to the extent to which the present supplies of water may be made to act for cleansing?—Yes.

Since the house-drains, when properly laid, are kept clean by the action of the waste water which they have to discharge, may not the junction or the branch drains be expected to keep themselves clean with their reduced amount of friction, and even with reduced falls?—They may.

As a matter of fact, where the drains and junctions are tolerably well laid, do they not keep themselves clear of accumulation, and consequently need no additional supplies of water?—They do.

When you speak of the tubular drains, are not the pipes at present and hitherto manufactured very imperfect?—They are, both in form and finish. A great many of the quality called "seconds," as well as of common red clay pipes, are used by private bricklayers when they can escape supervision.

Do not the potters continue to make right-angled junctions, and other improper forms of pipes?—Yes; because the importance of better forms is not generally understood, and a trifling saving of 9*d*. per pipe is made by using a straight in connexion with a right-angled pipe, instead of a curved with an acute-angled junction.

Will a 4-inch tubular drain take off the water falling upon the roof, and yard as well as that coming from the interior of a house of the largest class?—It will, if properly laid at an inclination of not less than 1 in 120.

What number of fourth-class houses may be drained by a 4-inch drain?—This will vary with the inclination and the extent of ground attached. In 1848 I drained five houses through such a pipe, and it has answered ever since perfectly and without any stoppage. Since then I have laid out the drainage of several blocks of 8, 10, and 12 houses, through 4-inch pipes where the inclination was good, that is to say, 1 in 30 to 1 in 60.

What quantity of water and of rain respectively formed the basis of your calculations?—100 gallons per house water-supply, and two inches of rain on the total area occupied by houses, yards, and gardens; the

Mr. Grant. combined quantity to be discharged by house-drains in two hours; for example:—

20 houses occupying an area of .	10,000	square feet.
Two inches rain on this . .	1,666	cubic feet.
20 houses supplied with 16 cub. ft. each	320	
	2)1986	cub. ft. discharged in 2 hours.
	60) 993	cub. ft. in 1 hour.
	16·55	cub. ft. per min.

A 4-inch drain laid at an inclination of 1 in 50 would discharge double the large quantity allowed in the above case for 20 houses; or, in other words, discharge 2 inches of rain and the daily supply of water in one hour.

What may be the proportion which the drainage from the interior of the house and the rainfall allowed for in your calculations bear to each other?—This varies with the number of houses per acre, but in a large district the quantity of rain calculated upon as likely to fall and be discharged in 24 hours was 15 times the amount of house drainage.

You were directed by the Works Committee to report on the means of the combination of the water supply with the house and general drainage works for the complete drainage and cleansing of a block of houses comprising the fever-nest known as Jacob's-island, Bermondsey?—I was.

What was the extent of the block of buildings you so laid down?—The total area was about 50 acres, the area built upon about 41½. The number of dwelling-houses, 1317; of granaries, manufactories, and buildings other than dwelling-houses, about 50 more; the average number of houses per acre being 32.

Will you state the sizes of house-drain branches and main or trunk drains you propose?—The house branches to closets are 4 inches diameter; to sinks 2 and 3 inches; the main lines are 6, 9, 12, 15, and 24 inches.

How many principal mains are there, and what are their sizes at the outlet?—There are four main drains; one measures at the outlet 24 inches diameter, to take the drainage of about 23 acres and 630 houses, besides making allowance for 10 acres and 670 houses more, which may be added at a future time. A second main line is 15 inches diameter at the outlet, to take the drainage of 10 acres and 364 houses, besides providing for 255 houses which may be added at a future time. The third main line is 9 inches, to drain 3¼ acres and 162 houses, besides providing for three-quarters of an acre and 107 houses more which may be added. The fourth is 12 inches at the outlet, to drain 6 acres and 177 houses, besides half an acre and 140 houses more which may be added at a future time. Provision is made for still further, if required, concentrating the streams of drainage into one line.

Supposing that you had an order of Court for the execution of this combined work of water-supply and drainage, within what time do you consider it might be executed?—From three to four months.

How much of the Surrey and Kent district might be with safety similarly drained in blocks separately, with the aid of the general and subterranean surveys?—All the more densely-built and most necessitous part might be similarly drained into the best of the existing sewers which surround the blocks. The outlets could be afterwards connected, and concentrated in the direction most desirable. Mr. Grant.

In this part of Bermondsey have you found many house-drains constructed under the former Surrey and Kent Commission?—Most of the houses drain into cesspools, but there are a few drains connected with the sewers in Great George-street and one or two other streets.

What was the size of house-drains made most recently before the late Surrey and Kent Commission?—9 and 12 inch brick barrel-drains; about three or four years ago 15 inches; and if to more than three houses, 18 inches.

What is the area of friction of these drains?—If they were full, the area of friction would be, in 9-inch drains 2·356 feet; 12-inch drains, 3·1416 feet; 15-inch drains, 3·927 feet; 18-inch drains, 4·712 feet; but inasmuch as the stream of drainage from a house of any size will never fill the whole area of even the smallest of these drains, the actual frictional area varies with the quantity of water passing through them.

What is the frictional area of the tubular drain you provide for a house?—In a 4-inch, if full, 1·047 feet, or one-third that of a 12-inch drain.

Supposing you were to drain from the back instead of the front, what difference would it make in the length of the house-drains?—It varies; but the average of many blocks in different localities may be stated in round numbers to be by front drainage *more than twice* the length of drain that is required by back drainage; in some cases it is three times.

Then if the frictional area of a 12-inch brick barrel-drain is three times that of a 4-inch pipe, and the length is double, the total frictional area of the one must be very greatly in excess of the other?—About six times in the case supposed.

Would it not be only in case of difficulties as to property that you would drain from the front instead of the back?—Only in such cases. For instance, in the Bermondsey block there are 21 houses which must be drained separately, as the mill-stream is immediately under and at the back of them; but, excluding these, there is but one house in a hundred through which a drain would need to be laid.

Is there the same disproportion in the size of the main sewers formerly made and those you have laid and recommended in different places?—There is.

What are the sectional areas of the main-lines you have proposed and those which exist in similar streets?—The sectional area of the 12-inch main pipes is ·7854 foot; of the 15-inch ·98175; the area of a very common size of sewer in similar streets (a sewer 5 feet high by 3 feet wide, semicircular top and bottom) is 13·07, or from 13 to 17 times the sectional area of the pipe-sewers.

Supposing the portion of Bermondsey formerly referred to were to have complete house-drainage as well as main-drainage on the plan which was formerly recognised, what would be the proportional frictional area?—Probably four to six times that of the system proposed.

And a proportional excess of water to keep the drains clear?—Yes, more.

Mr. Grant.

What the difference of cost?—This is difficult to ascertain precisely, but the averages of several blocks carefully calculated are from six to ten times that of the tubular back drainage.

What is the actual amount of deposit in the cesspools and such sewers as there are in the district?—There are in 648 cesspools about 30,000 cubic feet of soil, besides that in the sewers, which is very great, but constantly varying.

What difference of fall in the house-drains may there be by back and front drainage?—Never less than double in one case of the fall in the other, and generally much more.

What advantage in point of fall in a flat district like the one in question does the use of tubular sewers give you over the main lines of brick sewers?—In the one case a fall of from 9 to 10 feet has been obtained in about half a mile, whereas with brick sewers this would have been reduced to 5 or 6.

Suppose that it had been required to keep such drains and sewers in good action under the former plan of drainage, by what amount of water or arrangement of water could it have been effected?—I do not see any mode of keeping clean by any self-acting process such large sizes of drains and sewers, especially in a flat district.

You have doubtless observed cases where water carrying soil or detritus in suspension down proper inclinations was arrested by the closing of the outfall, as in the case of the old Surrey Commission sewers, which are below high-water mark during the high tides?—This is an inevitable and universal consequence in the Surrey and Kent or any similarly situated district drained on the intermittent system.

Such water when so arrested of course deposits the matter in suspension?—It does.

Now, when the surface sewer-water so arrested and detained during high-water (upon the intermittent system of drainage in Surrey) is discharged by the opening of the sluices at low water, does it lift and remove all the matter so deposited?—No: only that which is held in suspension.

The surface sewage-water is then merely decanted off by the opening of the sluices?—Exactly so. The grosser matter has to be removed either by hand labour alone, or in combination with large bodies of water flushed out.

What, from your own experience and observation in this district, do you consider the effect of ponding up the sewage by the intermittent system of drainage?—1. That it requires that storage room should be provided not only for the ordinary amount of sewage collected during the six or seven hours that the outlets are closed, but for the extraordinary falls of rain which sometimes occur during high water. 2. This storage room is obtained in the most expensive manner by making prolonged reservoirs, thereby making the most extravagant use of materials. 3. That the sewage, instead of being got rid of from every house and street as rapidly as it is generated, is retained to the detriment of health and comfort. 4. That during this detention the grosser particles are deposited and accumulate at such a rate as to require constant manual labour for the expulsion of the deposit. 5. That the discharge into the river can take place only at the most objectionable time, namely, at or near low water, when the return of the tide carries the sewage up the river instead of carrying it away. 6. That the limited fall is made still

less by the necessarily large size of the sewers, and the great length to which such main lines must extend. 7. That the sewers require expensive adjuncts in the shape of side-entrances, flushing and ventilating gratings, the cost of which, added to the constant expense of cleansing, makes it a very expensive mode of drainage. Mr. Grant.

What is the nature of the inclinations of the present main lines of sewer in the Surrey and Kent district?—In many cases they are on a dead level for considerable lengths. An inclination of about 3 feet per mile may be taken as an average on the main lines. The fall is so trifling that the flushing-men are in the habit of turning the water in either direction in some of the sewers.

Of course such inclinations are quite inconsistent with a proper discharge of the sewage?—They are; even if the outlets were constantly open the sewage would not pass off with sufficient speed to prevent deposit.

What upon this intermittent system of drainage would be the additional quantity of water required to raise and carry away all the matter deposited during the interruption of the first flow from the house-drains, and from the branch pipe-sewers which drain blocks of houses?—No additional quantity has been found to do so by any natural or self-acting process. More or less manual labour, according to the inclinations and other circumstances, has to be employed in conjunction with the force of water, to keep such sewers at all in working order.

The additional supply of water required in the intermittent or sewer reservoir system of drainage must be sent in by pumping, or derived from reservoirs or new water-works?—By one or other of these means.

It follows, then, from the facts observed—does it not?—that by pumping at the lower level, so as to lift the sewer water and continue the flow, less water and less pumping will be required than will be necessary at the upper end and on the intermittent system of drainage, and to remove the matter deposited in consequence of the interruption of the flow?—It does.

It is then only a question of a larger or smaller amount of pumping?—Precisely so in the case assumed.

And the least demand for water would be by a tubular system with direct pumping?—It would; with the additional advantage of continuous flow.

If the house-drains keep quite clear, the junctions, *à priori*, will keep themselves clear?—Yes; a very important point to be attended to in laying out drainage is to unite the streams and concentrate their flow as much as possible.

Then, as far as house-drains are concerned, can you contemplate the want of any additional supplies of water to keep them clean?—With a complete tubular system of drainage, I believe the present supply, properly delivered and distributed, to be sufficient for drainage purposes.

According to all your experience, any system of house-drains, union branches, or trunk-sewers, that collects the deposit, is faulty in construction?—Yes; the processes of flushing or cleansing and ventilation are the necessary attendants only of a faulty system of drainage.

At present there is constantly a large amount of evaporating surface of decomposing refuse in the block before referred to?—There is; many of the cesspools are close to and immediately under the houses. Some of the houses are built over the filthy tidal stream, and others close to stagnant ditches of the most offensive character.

Mr. Grant.

It is stated that the block of houses at Westminster already drained with pipes keep themselves clean; thus where this plan is adopted in connection with a supply of water no matter of course remains to decompose?—It passes off immediately it is generated.

You examined, some months ago, the drainage of the Cloisters of Westminster Abbey, by order of the late Metropolitan Commissioners of Sewers: what was the result of your examination?—I examined every inlet on the surface, whether closet, sink, or rain-water pipe, and examined the outlets into the main sewers under; and I found them all perfect. The pipes at the outlet were as clean as when first put in some seven or eight months before.

And that would be provided with probably one-third the water now supplied?—I believe so. There was a large tank, from which one length of the pipes could be flushed at pleasure; but it did not seem ever to have been required, the water ordinarily coming from the houses being sufficient to keep the drains always clean.

Were the residents in the Cloisters satisfied as to the efficiency of the drains?—Most perfectly so. The Very Rev. the Dean and the occupants of every house expressed themselves pleased with the improvement the new drainage had effected.

Whilst under a system of constant supply of water, combined with a system of tubular back drainage, there would be the saving of probably half the water now used;—you were directed to estimate from survey what would be the saving in constructing the drainage adapted for thus economising of power and water; distinguishing from the cost of back tubular drains the expense of tubular drains through each house into the street; and also setting forth the cost of brick drains and sewers on the system pursued previous to the investigation of the Metropolitan Sanitary Commission; stating also the frictional area of each?—I was.

You have made these by measurement, &c., on the plans?—Yes.

Give in the plans from which you estimated the comparative cost of back and front drainage and water supply?—The plans were made chiefly to show by comparison the relative merits of back and front drainage, but they as clearly illustrate the economy of laying the water-pipes at the back instead of through each house.

State the comparative results of the several blocks?—

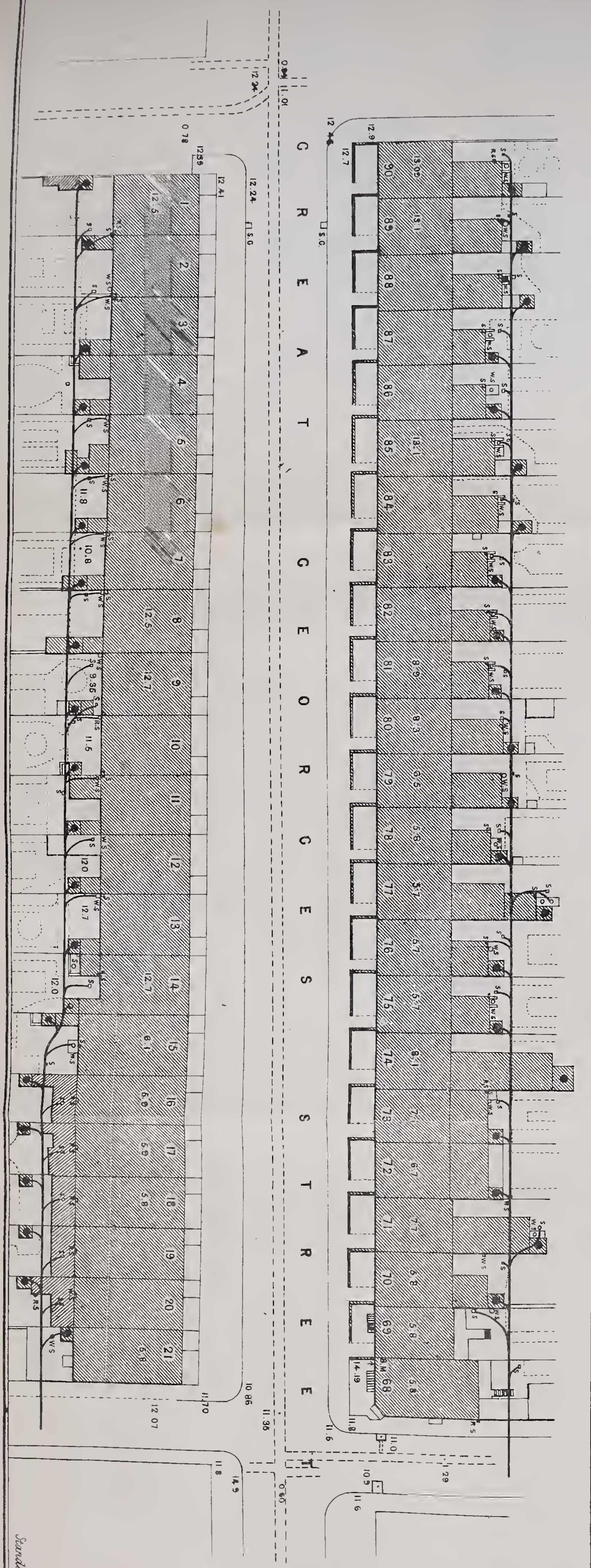
In one block of 44 houses,—

The length of drains by back drainage was 1544 feet.
Length by separate drainage,   feet.
Cost (exclusive of pans, traps, and water in both cases) of back drainage, 83*l.* 12*s.*, or 1*l.* 18*s.* per house.
Cost of separate tubular drainage, 467*l.* 9*s.* 6*d.*, or 10*l.* 12*s.* 6*d.* per house.
Cost of separate brick drains, 910*l.* 19*s.*, or 20*l.* 14*s.* 1*d.* per house.

In another block of 23 houses,—

The length of back drains was 783 feet.
Of separate drains, 1437 feet.
The cost of back tubular drains, 45*l.* 12*s.* 6*d.*, or 1*l.* 19*s.* 8*d.* per house.
Of separate tubular drains, 131*l.* 13*s.* 6*d.*, or 5*l.* 14*s.* 6*d.* per house.
Of separate brick drains, 305*l.* 7*s.*, or 13*l.* 5*s.* 6*d.* per house.

PART OF SURREY & KENT DISTRICT.

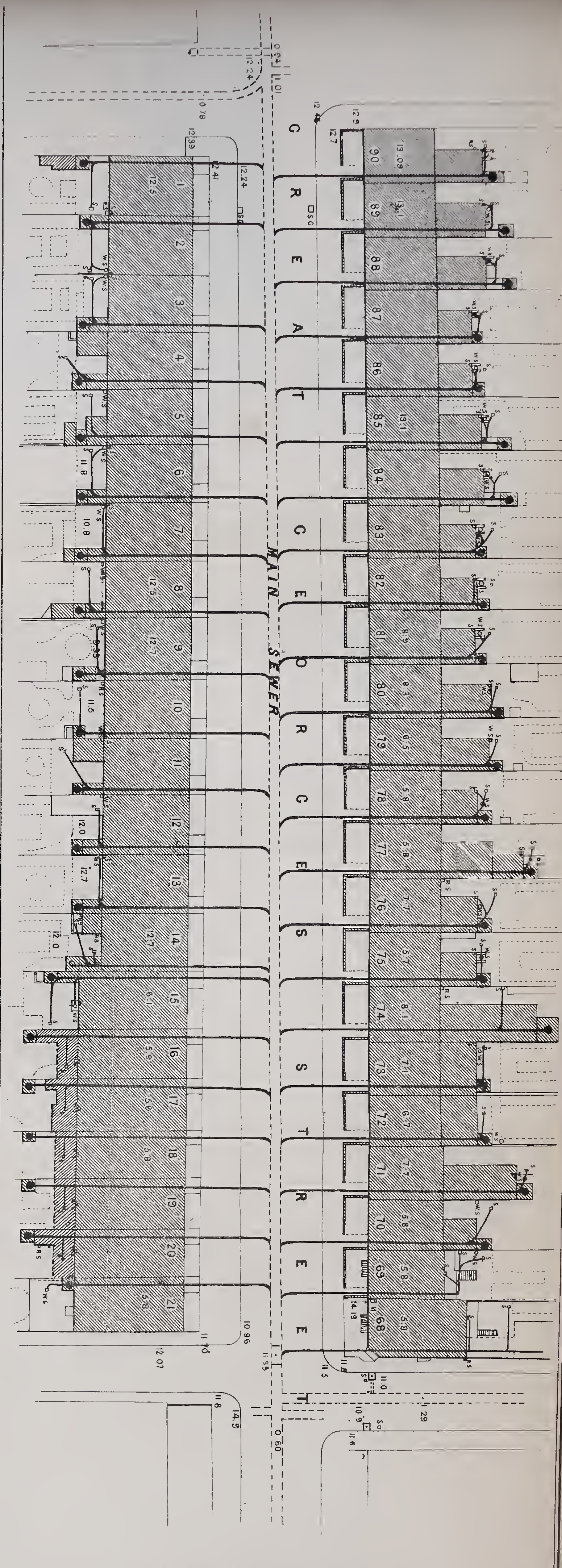


BACK DRAINAGE.

Total length of Drains 1544 Feet

Estimated Cost £ 83 11 10

Note. The Black Spots indicate existing Cesspools



SEPARATE DRAINAGE.

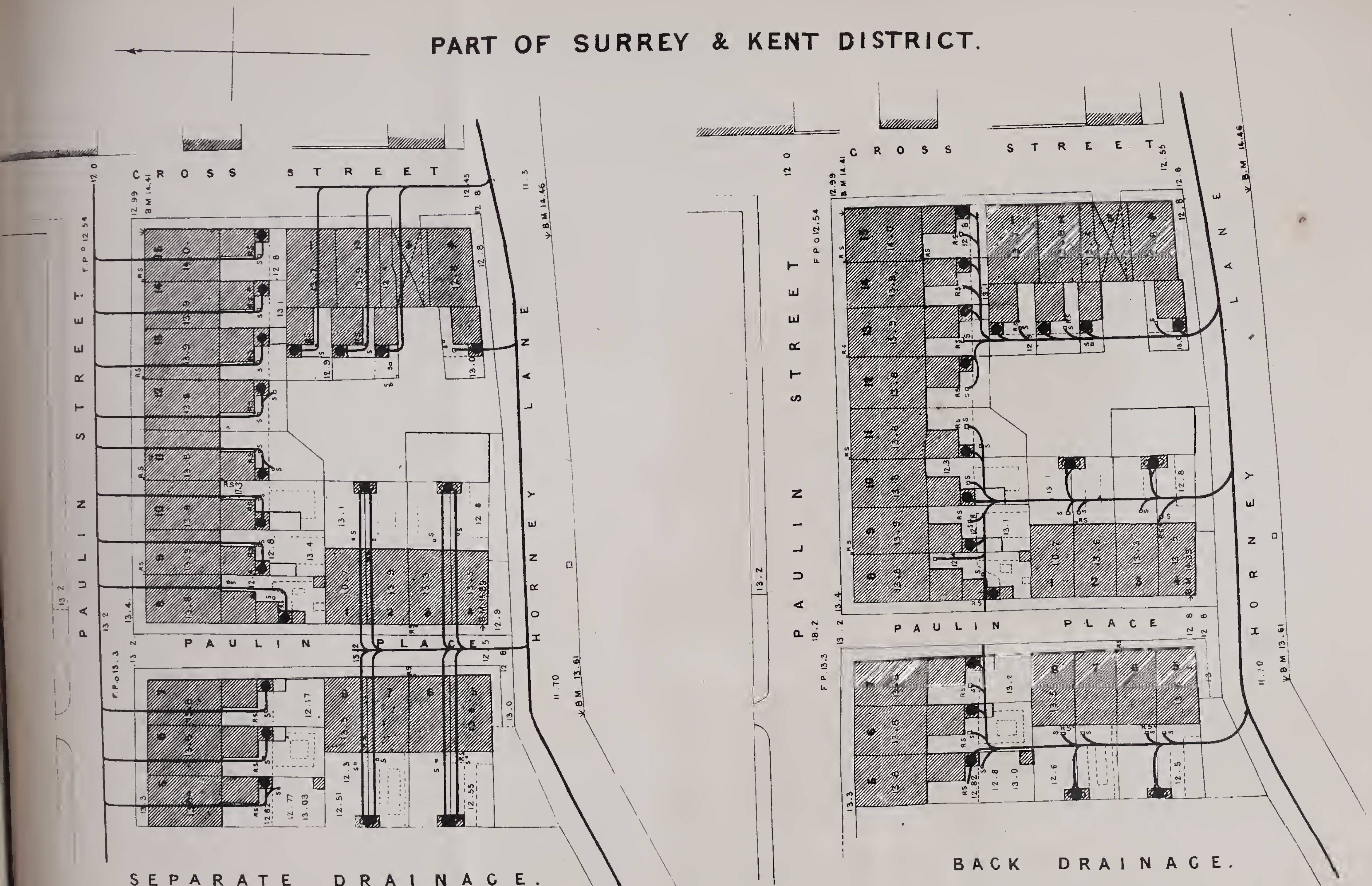
Total length of Drains 3686 Feet.

Estimated Cost with Brick Barrel Branches £ 910. 19 0

Dº Dº 4 in. pipe Dº £ 467. 9 6

208 E 114 Standidge & Co Litho Old Jewry

PART OF SURREY & KENT DISTRICT.



SEPARATE DRAINAGE.

BACK DRAINAGE.

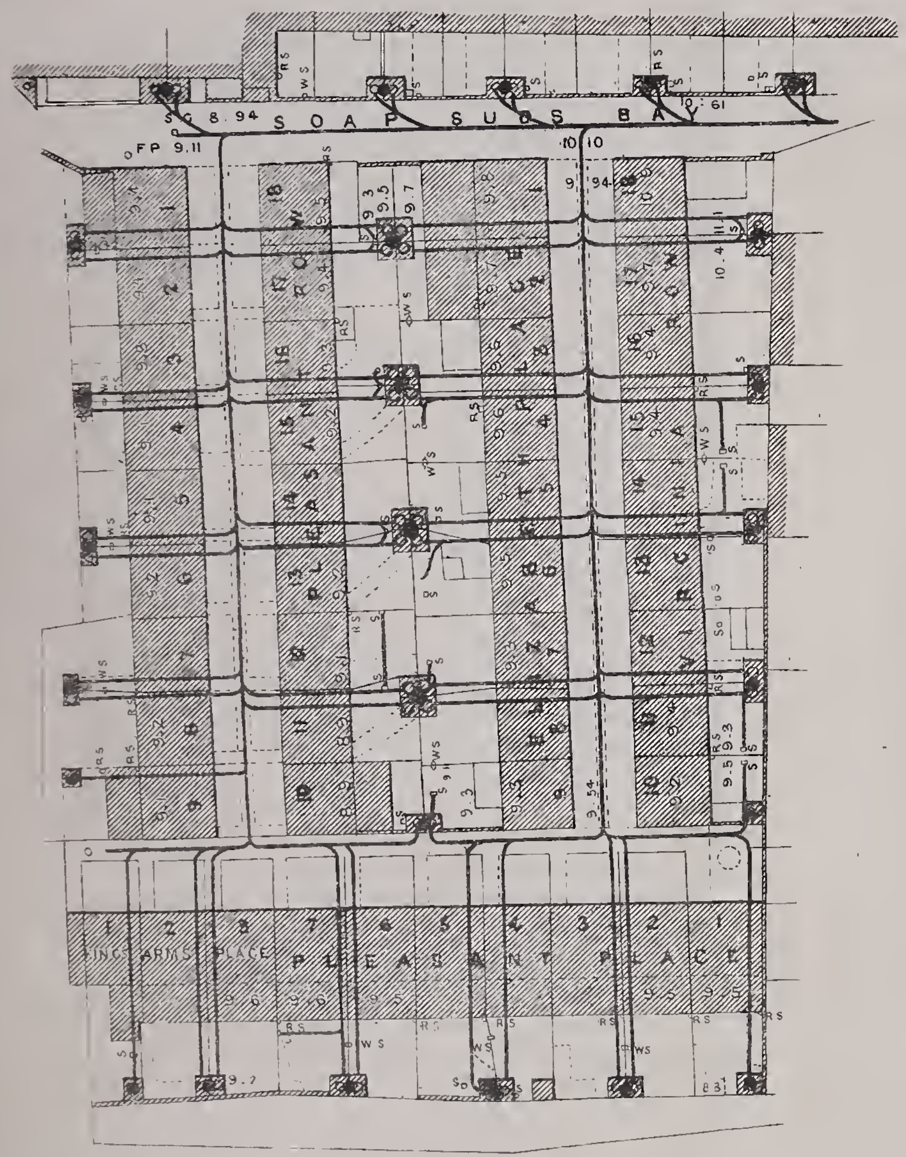
Total Length of Drains 1437 Feet.
Estimated Cost with Brick barrel branches £305. 7. 0.
D° 4 inch pipe D° £131.13.6.

Total Length of Drains 785 Feet.
Estimated Cost £45. 12. 6.
Note.—The Black Spots denote Cesspools.

207.P.114.

Standidge & C° Litho Old Jewry.

PART OF SURREY & KENT DISTRICT.

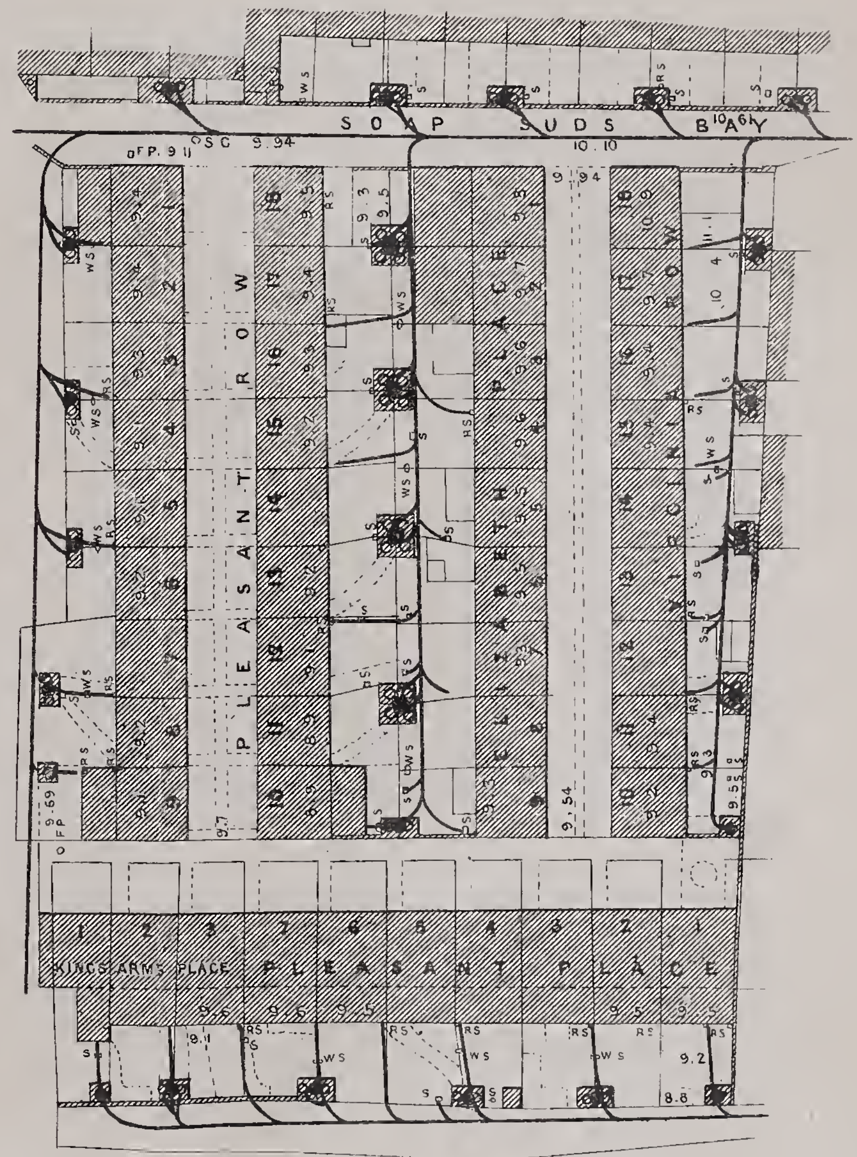


SEPARATE DRAINAGE.

Total Length of Drains 1892 Feet.

Estimated Cost with Brick barrel branches £ 390.4.0.

D^{o} 4 inch pipe D^{o} £ 178.19.8.

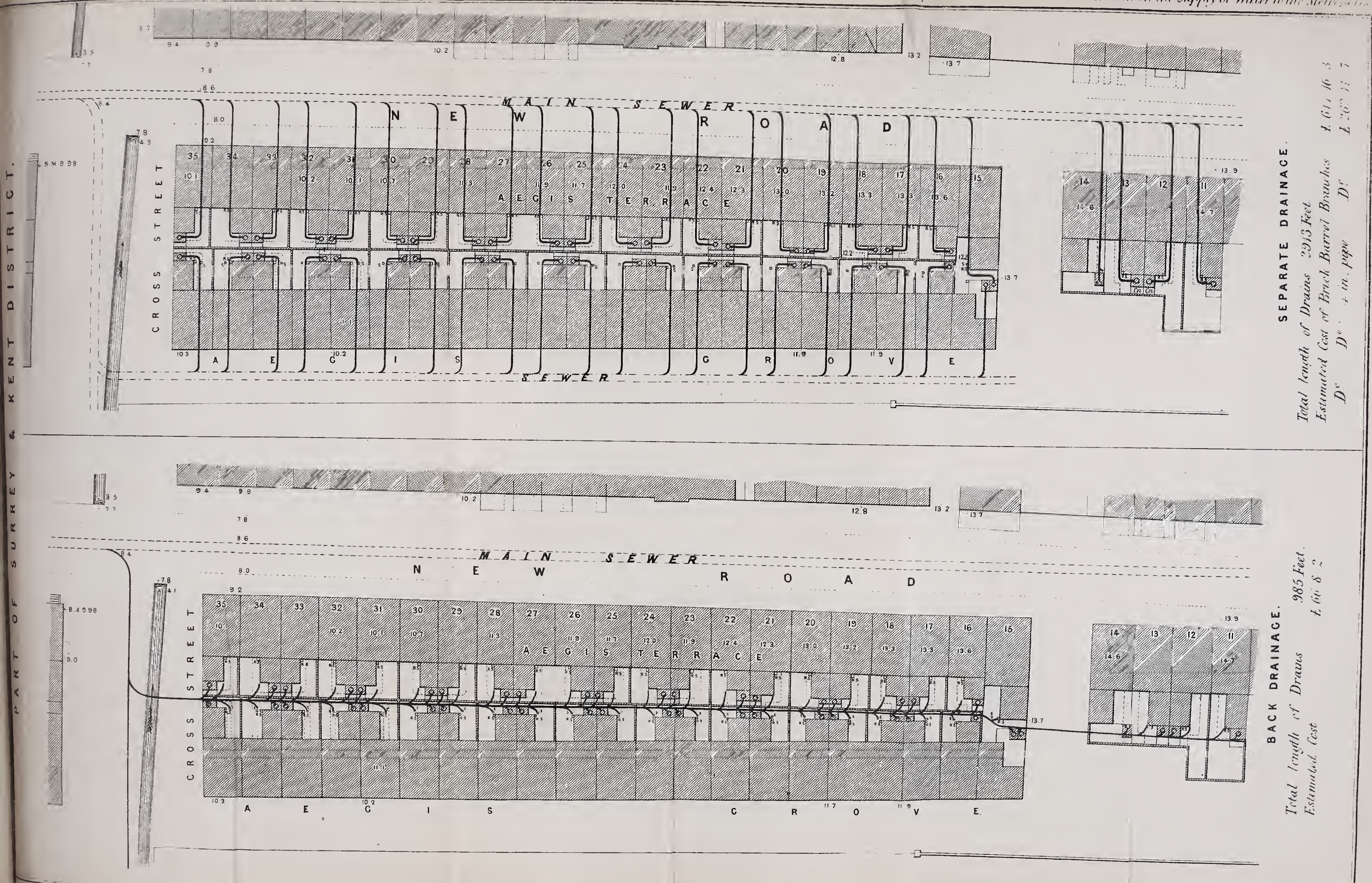


BACK DRAINAGE.

Total Length of Drains, 1143 Feet.

Estimated Cost £ 65 . 5 2.

Note. – The Black Spots denote Cesspools.



Standidge & Co. Litho. Old Jewry

In another block of 46 houses,— Mr. Grant.

The length of back drainage 1143 feet.

Ditto by separate ditto, 1892 feet.

The cost of back tubular drainage, 66*l.* 5*s.* 2*d.*, or 1*l.* 8*s.* 9$\frac{3}{4}$*d.* per house.

Ditto of separate ditto ditto, 178*l.* 19*s.* 8*d.*, or 3*l.* 17*s.* 10*d.* per house.

Ditto of separate brick ditto, 390*l.* 4*s.*, or 8*l.* 9*s.* 8*d.* per house.

In a fourth block of 46 houses,—

The length of back drains 985 feet.

Ditto of separate ditto, 2913 feet.

Cost of back tubular drainage, 66*l.* 8*s.* 2*d.*, or 1*l.* 8*s.* 10$\frac{1}{2}$*d.* per house.

Ditto of separate ditto ditto, 262*l.* 11*s.* 7*d.*, or 5*l.* 14*s.* 2*d.* per house.

Ditto of separate brick ditto, 614*l.* 16*s.* 3*d.*, or 13*l.* 7*s.* 3$\frac{3}{4}$*d.* per house.

Have you made arrangements for subsoil drainage as well as for relieving the surface of its water?—Yes.

Will you describe the nature of that arrangement?—It is simply to lay agricultural tiles, varying in size from 1$\frac{1}{4}$ to 4 inches, immediately under the other drains, in some cases over; and draining into the existing large brick sewers.

What would be the additional expense per house of this?—The cost averages 4*s.* 2*d.* per house in Bermondsey, and 4*s.* 4$\frac{1}{2}$*d.* per house in another large block.

What would be the expense per house of water-supply, drainage, and subsoil drainage?—These, including a dust-bin to each house and new closets where required, average 6*l.* 15*s.* per house; to pay off the principal and interest of which in thirty years would require 8*s.* per annum, or 1$\frac{3}{4}$*d.* per week.

Have you a good outfall for this block?—The best existing outfall is the main Duffield sewer, 5 feet in diameter, the invert of which is about 3 feet above the level of low water.

What size would the whole drainage area be?—About 350 acres might conveniently at a future time drain into the same point.

Then this block being formed, you can lead either to a lower artificial outfall than is at present provided, or to an overflow, which may be selected?—Yes, to either.

And this process may be carried out irrespective of any plan of drainage as to the main outfall?—It may be carried out at once without waiting for the settlement of that question.

Do you consider the present a sufficient and permanent outfall?—No, but as the best available.

Then you consider that it is important to determine, as soon as possible, upon a better outfall, but that the drainage of these wretched districts may in the mean time be laid and their condition improved without delay?—Certainly.

Are there not many such districts in which this might be done?—Yes; many.

What is chiefly the class of houses here?—About one-half of the whole number do not exceed 15*l.* per annum, and only 71 out of 1317 exceed 25*l.*

With one-third the length of pipes by back-drainage, will there not, on account of the increased force of the water, be less than one-third the chances of stoppages, consequently less than one-third of the annoyances from the intrusion of workmen to open drains?—There will.

Mr. Grant.

With regard to the objection which has been made to back-drainage, that, in case of stoppages in the house-drains, one tenant suffering annoyance is at the mercy of another on whose premises the obstacle may exist, although it may not inconvenience the latter, do you believe it possible to avoid this difficulty?—Yes; if the Commissioners of Sewers took entire control over house-drains as well as mains, I have no doubt they would find respectable persons who would contract to keep in working order the house-drains of a district for 6*d.* per house per annum.

Have you in the course of your ordinary duties, examining into complaints of imperfect drainage, frequent complaints of bad smells from house-drains passing under the floors?—Very frequently, as well as of the damp created.

Is it not a common remark of the complainants that these smells are worst "when the water is on," or "on water-days?"—It is.

What is the cost of flushing the old system of sewers?—This varies very much in different districts, being highest in the Surrey and Kent district. As far as I can approximately ascertain it, it amounts to about 2*s.* 3*d.* to 2*s.* 6*d.* per house per annum in the Surrey and Kent district, that is, including wages and works necessary for such purposes. This, however, would be most materially increased if the same system of brick sewers were extended into every street. The many houses which do not communicate with the present sewers reduce the average cost of flushing per house for the smaller number which do communicate.

What are the expenses other than wages?—The cost of flushing-gates, penstocks, side-entrances, ventilating gratings, and the cost of digging down to and breaking holes into the sewers at frequent intervals, where there are no side-entrances or casting-holes, and making good such breaches.

Were not attempts made to ventilate one of the sewers last summer, and what was the result?—Several attempts have been made, the last by means of the steam-jet, and also by passing the air of the sewer through a furnace into a factory-chimney. The steam-jet will ventilate a certain length of sewer, if it be ever so foul; and, for a special purpose, might be a useful means of preventing danger. By the factory-chimney there was a constant and sensible draught kept up, which would, I believe, justify the cost of making a connection with such of the present main sewers as were near tall chimneys, at least as a supplementary means of ventilation.

Would not the connexion of the rain-water pipes of houses be effective in ventilating the sewers?—Yes; I have connected them in a few cases where their heads were not close to or under bedroom windows.

Have you provided means of ventilation for the tubular systems laid out by you?—No; I believe ventilation, flushing, and additional supplies of water to be necessary only for an imperfect system of drainage, and that the cost of them would go far towards executing a complete and perfect system of drainage.

A block of houses at New Peckham has been referred to as a case which required periodical flushing. Can you state the conditions under which the drains were laid down and put in action?—The drains were put in by the owner very imperfectly, and without water to each closet, but with a flushing-tank to be used occasionally. One of the branch lines, more imperfectly laid than the others, got deranged, but the main line remained clear and in action.

Mr. Grant.

Have you also had occasion to examine the existing water-supply?—Yes; the district referred to is chiefly supplied by the Southwark and Vauxhall Water Company.

It appears to be admitted by the engineer of that Company that not above a third of the water pumped in is used, and that full two-thirds are wasted?—Mr. Quick has expressed a similar opinion to me, and I have no doubt, from my own observation, of its accuracy.

He also stated that, from the nature of the supply (being intermittent) and from the construction of the drains, accumulations take place, the drains become choked, and the water runs over; does that agree with your observation?—It does. From imperfect pipes and ball-cocks, and stand-pipes for courts without cocks, there is in the poorer districts more water wasted than is used; in fact, it is worse than wasted, for it is the cause of damp, dilapidation, disease, and injury wherever there is not perfect drainage to carry off the waste water.

Have you known of persons taking water for domestic supplies from ditches in your district?—In Bermondsey that is the case with 203 families, composed of 865 individuals, residing in 152 houses, chiefly in Jacob's Island and adjoining the mill-stream, which serves at once as an outlet for the drainage and the means of water supply.

Did the result of your inquiry from house to house show any difference in the amount of mortality during last summer among these 865 individuals and the other parts of the block where the inhabitants were supplied by the Water Company?—It showed an excess of 37 per cent. over the portion supplied by the Water Company.

Have you in other cases met with excessive mortality, which appeared due in any manner to the nature of the water used by the sufferers?—Yes; last summer, during the prevalence of cholera, I had occasion to report to the Metropolitan Commission of Sewers two remarkable cases of excessive mortality which were in my opinion clearly traceable to the contaminated water used by the inhabitants.

What were the circumstances in the first case?—The first case was that of a court called Surrey-buildings, Thomas-street, Horsleydown, consisting of 13 houses, the backs of which were towards Truscott's-court, of similar character and extent. In Surrey-buildings nine or ten persons died of cholera in five days, and in Truscott's-court not one. In the first court the people were supplied with water from a well on a level with the pavement, from which foul water drained into and polluted it; the other was supplied with pure water. This was the only point in which the two courts differed, namely, the water-supply; and whilst in one court one or two individuals died in every second house, in the other the inhabitants remained safe.

What was the other case you referred to?—That of Albion-terrace, Wandsworth-road, which consisted of 17 houses of a superior class, in which some 25 to 30 persons died in the course of 10 days. This terrace was supplied by a spring which passed through imperfect pipes and tanks close to cesspools and drains. The water got contaminated after a heavy storm of rain in July, and this frightful mortality occurred among persons in easy circumstances, whilst the population east and west of this terrace were not attacked. The water-pipes served the houses from No. 1 to No. 17 inclusive, and these were the exact limits of the ravages of the disease.

Mr. Grant.

In the Bermondsey block what proportion of the houses are supplied by the Water Company and from other sources?—Of 1317 houses, 1066 are supplied by the company directly, and 35 more by stand-pipes used in common; 152 by the filthy mill-stream, 56 by pumps, and 8 are without any means.

What is the average charge per house for water?—About 13*s.* 9*d.*, or rather more than 3*d.* a-week per house.

How many public-houses may there be in the block?—18, or 1 for every 72½ houses.

Are the houses damp or water-logged?—There are many in Wellington-street and Rose-court which have water standing under the floor and sometimes over it. The occupants pump it out when it gets over the floor.

Where do the tanners and other manufacturers get their supply of water from?—Some from the tidal stream, and others partly from the Water Company.

Has the character of the water in the mill-stream and ditches in the neighbourhood at all changed of late years?—It has of late years become much polluted from the increase of houses, the drainage of which falls into these ditches. Some seven or eight years ago hardly any of the houses were supplied by the Water Company; but about four years ago a great many of the landlords had water laid on to their properties.

What is the amount of poor's rate collected in the parish?—This year it is 3*s.* 2*d.* in the pound, and I believe amounts to about 18,000*l.*

What other rates are paid?—

	s.	*d.*	
Improvement rate for lighting, paving, and scavenging . . .	1	6	in the pound.
Sewers-rate	0	8	
Church-rate, about . . .	0	2	
Poor-rate (as before) . . .	3	2	
Total, about . .	5	6	

The water-charge adds about 10*d.* more.

What is the distance between fire-plugs?—From 60 to 80 yards.

How often are the inhabitants supplied with water?—For a portion of every day excepting Sundays.

Could the polluted mill-stream be entirely got rid of at present?—Apart from the opposition offered by the reputed owner to any interference with it, the stream could not be filled in until other means of drainage were provided.

Could it be got rid of if these works were executed?—It could be either filled up or kept constantly cleansed; the inhabitants would no longer be dependent on it for either water or drainage.

Have you met with instances of families being indebted to public-houses for their supply of water?—I have, in Bermondsey; also in another district in the neighbourhood of Old Kent-road; and in a number of houses at Battersea-fields. This practice was till lately much more common than it is at present; the publicans in poor districts paid a very high water-rate to the Company, owing to the large quantity used by them in the practice of selling about a thimbleful of gin and a pail of water for a halfpenny. The practice is by no means extinct now

Have you not estimates for carrying a supply of water into each house?—Yes; a constant supply into each house and closet in the district. Mr. Grant.

By what means, and at what cost?—By a tank elevated at a height of 35 to 40 feet, and at a cost to each house for the tank of 13*s*., for the pipes, &c., 29*s*. Total average per house, 42*s*.

Are you aware of any houses in that neighbourhood already supplied on the constant system?—Yes; there is a small block of eight or ten houses in Rose-court which are supplied by one tank, and have a tap in each house. The tenants expressed themselves to me highly pleased with it.

Do you think the same advantage would follow over the whole district?—It would, as a matter of course.

What, according to your estimate, would be the expense of service-pipes for carrying in water for a constant supply?—I have already given the estimated cost of the apparatus for water supply in one block; in another, the average cost per house is, for the tank, 17*s*.; for the pipes and cocks, 26*s*.: total, 43*s*. per house. In another, 50*s*., including tank, which would, however, supply as many more houses, and reduce the cost to 37*s*. 6*d*. per house. In another, it amounts to 30*s*. 6*d*. per house, including tank, which only amounts to 7*s*. 6*d*. per house total cost. In another case, where the whole of the pipes, mains and branches, would require to be laid, there being none at present, and where, from its peculiar situation, a constant supply may be given without a tank, the total cost would be 45*s*. per house. This, however, includes a large number of stables and several workshops attached to the dwelling-houses. All these estimates are made at prices for which a single house may be at present done.

Besides the expense, will there not be the objection to the mode of delivery by tank resulting from the consequent exposure of the water?—The tank would be covered, and the water constantly changing. But if the general supply of water were constant, or the Water Company would consent to supply this district on the constant principle, the tank would not be required, and its cost—850*l*., or 13*s*. a house—might be saved.

Then the cost of this tank is to be incurred with the view of not delaying the question of drainage till the settlement of the question as to a general system of constant water supply?—Entirely with that view.

But still the air would not be excluded from the tank?—It would not.

If you had to put a separate tank to each of all these houses, what would be the expense?—To afford the same advantages, about four times as much.

What size of mains are proposed for these houses?—There is already a main water-pipe in every street. Their size varies from 3 to 12 inches.

What size would the tank be?—It would hold 3000 cubic feet, or $1\frac{1}{2}$ cubic feet to each house. But the supply would be rendered constant and unlimited; the tank acting as a standpipe and reservoir in case of repairs being required to the main pipes.

How many houses would that supply?—1317 in the first instance, and more eventually if required.

Apart from the expense of the tank, what would be the expense per house for water apparatus?—Twenty-nine shillings.

Mr. Grant.

It is presumed that you give your estimates at such prices as you believe the contracts might now be obtained for?—I have in everything, both for labour and materials, allowed the present prices given for small works, and would undertake to get twenty respectable men of capital to undertake the execution of the works in the most complete manner for the estimated cost, and that without competition.

You stated a saving in length by back drainage, apart from its other advantages, to be at least one-half. What would be the saving of supplying water *de novo* at the back?—The saving in length would be about the same, and the cost of laying the pipes from the front would, on an average, be fully double the cost required to take them at the back; in many cases more.

Would there not be a probable gain to the tenant if the water-pipes were laid under the same contract with the drains?—The same trench would serve in most cases for both, and thereby cause a saving as well as in the cost of relaying the paving.

Besides the Bermondsey block of drainage you have laid out water-supplies and drainage at the back in other blocks?—Yes, in four or five other blocks.

In what proportion of cases in these other blocks did you find it necessary to carry water distributary apparatus and drains through the houses?—In one case of 51 houses, another of 226 houses, and a third of 270, there was not one house in which the water-pipes or drains had to be carried through the house. In a small block of 35 houses 2 houses would be passed through. In another of 124 houses, the piping would be carried through 4 houses.

For all these results, then, for an improved domestic water supply, and for an improved mode of cleansing, you calculate that not only could no additional supply of water be wanted, but that scarcely one-half would be wanted?—On a better system one-half the quantity at present supplied to each house by the Southwark and Vauxhall Water Company would amply serve for the domestic supply and keeping clean a proper system of tubular drainage. *At present that company pumps into the district a quantity considerably more than equal to* 100 *gallons daily to each house, and the total rainfall upon the area, united.*

From the disuse of separate ball-cocks and tanks, is there any doubt that the quality of the water would be greatly improved?—I have no doubt of it.

Supposing the water to be delivered cool, would there not be less decomposition in the matter carried away?—There would; but with a perfect system of drainage there would be no time given for the process of decomposition to take place, at least upon the premises.

Since the plans have been carried out at the Cloisters of Westminster, is it not stated that there have been no smells from the drains?—Such was the result of my examination made from house to house; and also that fever, which had previously prevailed, had ceased.

Can you tell what the present water-rent is additional per house, and over the whole district of which you have formerly spoken?—The total revenue is 763*l*. 12*s*. 6*d*., being about $4\frac{1}{2}$ per cent. of the gross rental. The annual charge is 3*s*. 6*d*. per room, with a deduction to a landlord farming it of 20 per cent.

Do you find this about the average water-rate in other parts of your

district?—In several districts which I have carefully examined, the water-rate varies from $4\frac{1}{2}$ to $5\frac{1}{2}$ per cent. on the gross rental. Mr. Grant.

Do you not consider it equally desirable, for the sake of the tenant as well as for the care of the general apparatus, that the service-pipes should be under one and the same inspection?—I do. The chief obstacle, I believe, to the water companies giving a constant supply of water is, that at present there is no security for the soundness of the supply-pipes and water-cocks; and the waste consequent upon this obliges them to shut off one part of the district whilst they are supplying another.

Would it be practicable not only to get this done, but also to get it kept in order for a certain number of years?—Perfectly practicable.

Would it not be practicable to have the main drains and water-pipes looked after by the same person who superintended the water?—It would.

Will you look to this examination of W. C. Mylne, Esq.?—

[Extract from the Examination of *W. C. Mylne*, Esq., C.E.]

"Were you consulted as an engineer on a plan for supplying Paris with water?—Yes, I was, in 1817 and in 1823: I am still engaged upon that subject.

"In the plan you have proposed, did it not form a part that the tenant's communication-pipes should be provided and laid down by the company as an essential part of the works of distribution?—Yes, I considered it the most desirable that it should do so.

"Will you state the advantages to the tenant or the public that were proposed from that part of the plans over the common method, leaving every uninformed occupier or owner to the necessity of employing a separate plumber to complete as he might that part of the general machinery?—In the first place, it would effect a considerable saving of capital; in the next place, it would be done on principle and in a superior manner. The trading plumber has no motive to carry out improvements, two lengths of pipe may be put where one would serve. As an example of the improvement proposed to be introduced in detail, I had intended to introduce lead pipes, with screw-joints, similar to those used in wrought-iron pipes. The cost of these joints was not above 1*d.*; they would have superseded completely the plumber's joint; and neither the plumber, nor his irons, fire, ladle, nor labour were necessary, and an expense of 1*s.* 6*d.* per joint was saved. In various respects we should have economised the machinery for distribution.

"This portion of the machinery being laid down by the company, was it proposed to charge at once the expense of this outlay upon the owners or occupiers, or to charge for it a rental?—It was proposed to charge interest on the extra amount of outlay as a rental.

"Then these tenants' communication-pipes would have been under the same general care as the mains or iron pipes of distribution?—Yes, that was my view; and my opinion has always been that, as public traders, that which is best for the public customer is ultimately the best for the company by whom they are supplied.

"What would be the extent of probable advantage to the public in respect to the saving of repairs?—Very great: one public officer would have been appointed to attend to the laying on of all houses, as also to all the repairs. Under ordinary circumstances, when an accident occurs within or without the building, the tenant has to think how it will be repaired, and has to consider how he is to pay for it, and who is to be sent for; the plumber, when he arrives, makes his repairs in his own way, which is without reference to any general system. Two-thirds of the labour, on the occurrence of any accident, is in the journeys, which would be rendered unnecessary under a general system, by which, on such an occurrence, the

Mr. Grant. inconvenience may be remedied at once. The advantage of having the tenants' communication-pipes placed under one general system would have been, that they would have been so laid down at first as to have avoided many of the incidental injuries which they are liable to from frost and accidental circumstances, as well as being placed where they could readily be repaired.

"In the case of a company undertaking to lay down these pipes, would not the repair of them form part of the general charge, and be added to the rent?—Yes; frequently an accident occurs towards the end of the tenant's term of occupation in the premises, and the cost of repairing it may be equal to his quarter's rent. Being a tenant at will, or near the termination of his lease, he says, 'I may be turned out shortly; it is not worth my while to undertake it;' and it is left undone if within his premises.

"Increased dilapidation must be the consequence?—Of course: that naturally results.

"In that plan, then, you assumed as a principle that the tenants must be relieved of the immediate outlay, and the expense be spread over a period and collected as a rent?—Yes, certainly. This was the more necessary at Paris, where the dwellings are extensively occupied in flats (as at Edinburgh and Glasgow, and in several other towns) as distinct tenements. Each flat would be held for various periods, some of the nature of tenancies at will, some of them of the nature of leasehold, and under every description of interest and period of occupation. Of course, the parties having short intervals would not undertake the immediate expense of the outlay for the permanent improvement, nor would the persons in the lower apartments pay for the repairs in any lower part of the building necessary for the supply of any upper apartment.

"Did the plan of comprehending the tenants' communication-pipes and the whole machinery under one general system offer any advantages in respect to economy and sufficiency in laying down the iron pipes?—In a new town there would often be much public economy in laying pipes on both sides instead of in the centre of the streets; there would be the saving of lead pipes, the saving of repairs to these lead pipes, the avoidance of the inconvenience and expense of breaking up the roads for that purpose, the saving of the inconvenience to the tenants in the event of frosts, from there being less of their smaller pipes exposed. In a street of 60 feet wide the saving of lead pipe would be about 20 feet in each tenant; that is, if the street is built upon each side there would be 40 feet of leaden pipe saved in a house frontage of (say) 20 feet; therefore 20 feet of iron extra would avoid the use of 40 feet of lead.

"In carrying the water up the higher houses, would you not have introduced iron pipes?—We should have introduced iron wherever we could. At that time, when lead was very dear, I contemplated the use of tinned copper pipes."

Will you state whether you agree with him as regards economy to the tenant?—I do.

In laying down house-drains, what proportion of the expense does the cost of pipes bear to the other outlay?—The cost of pipes is at present about one-half of the whole.

Do you agree that, as has been stated, the pipes for the supply of water should be laid lower than at present, for the sake of coolness and preserving the water at a middling temperature?—I do. It is a point of great importance, which has not always been attended to.

Does it appear to you that the water can be carried into the premises of the poorer description of tenements, or indeed of any class, by service-pipes on the constant system of supply, and carried away from them by waste or drain pipes, if the work is to be dependent on the separate

Mr. Grant.

efforts of individual householders, or by requiring immediate outlays, or by any other system than by common contracts and repayment by annual instalments of principal and interest over periods of time?—It does not; the most stringent legislative enactment would never effect these improvements if the cost were to be paid in one sum. It would, in many cases, be most unjust; but it is, in the majority, a simple impossibility.

From your interviews with owners and occupiers, do you doubt the practicability of carrying out improved works of water-supply, drainage, and cleansing by means of distributive charges?—I do not; so far from its being impracticable, and considered so by owners or occupiers of houses, one instance will suffice to show. At the present time I am in communication with two parties in the district, large proprietors of house property, who are anxious to carry out works of improved drainage, but who will not undertake them if they are to pay down the cost of these works in one sum; but, if the charges are distributed over a period of years, they would at once, and cheerfully, carry them out.

With respect to the purity of the river water, under what circumstances could the sewage pass into the Thames with the least amount of pollution to its waters near the metropolis?—At high water, when it would be permanently removed below the point of discharge a distance equal to the difference of ebb and flow.

If discharged at low water, at what distance below the metropolis must the outlet be to prevent the sewage being sent into the metropolis? —A distance at least equal to the space traversed by the flood-tide: probably from 7 to 10 miles below the lowest part of the metropolis.

What proportion of the Surrey and Kent district is under Trinity high-water mark?—About 9 out of 27 square miles.

The low-lying part embraces the oldest and most densely-built portion?—It does.

With sewers 5 feet in height, having outlets at the level of low-water mark, what is the greatest amount of fall which can be obtained in this flat district?—The crown of the sewer being at least 4 feet under the surface of the ground, where on a level with high-water mark, the fall would be about 9 feet, which, if divided over 3 miles, would give 3 feet per mile.

When heavy rains fall, do the present main sewers carry them off during the five or six hours that the outlets can be kept open?—No; it takes four or five days, or from eight to ten tides, to reduce the run of water in the Duffield to its ordinary amount after a heavy fall of rain.

Is there not a vast amount of animal matter passes through the sewers?—Yes. After the Friar-street was cleansed, large masses, like bolsters, of the entrails of horses and sheep, clotted together and in a state of putrefaction, were sent into the Thames. These were the refuse of the knackers' yards, catgut manufactories, and slaughter-houses.

What is the distance between the conduit-pipe of the South Lambeth Water-works and the outlet of the nearest sewer?—The conduit-pipe, by which their well is supplied from the Thames at all states of the tide, is immediately below the south end of Hungerford Bridge; and the outlet of one of the large sewers is close to the south end of Waterloo Bridge. The distance between is about 200 yards.

Mr. Cresy, jun.

Mr. E. Cresy, Jun., examined.

Are you not Assistant-surveyor in the Sewers' Office?—Yes,

Were you not instructed by the Works Committee of the Sewers' Commission to examine the house-drains of a block of houses at Hanway-yard?—I had the honour to be nominated by minute of Committee, in September last.

Was not that block of houses characterized from the houses being placed more back to back than usual, and their having no back yards?—The annexed very beautiful and correct detailed plan of the locality in question, prepared by Assistant-surveyor Smith, exhibits in the best manner the nature of the distribution of the houses, and their situation with respect to each other; those in Hanway-street may be specially cited as instances of this very pernicious custom.

Did not the Committee propose the abolition of cesspools, and the substitution of a soil-pan apparatus?—I was particularly instructed by the Committee to report upon these points, and indeed no system of house drainage can be considered at all complete which does not include these requisites.

What was the amount of evaporative surface of the cesspools and house-drains you found upon the spot?—From the crowded nature of site it was particularly difficult to discover the situation and extent of these receptacles, otherwise than by that unerring guide the sense of smell; in many cases when the premises were characterized by a powerful effluvia, the inhabitants avowed their ignorance of the existence of any cesspool, and assured me, that if such were the case, it could not have been emptied for upwards of ten years. From a-house-to-house visitation made for the purpose of ascertaining the fact, I deduced an *approximate* extent of about 8,500 superficial feet or about $\frac{1}{5}$th of an acre for the drains and cesspools over the whole area of nine acres, but in a long inhabited site of the kind under consideration, the whole soil becomes charged with decomposing animal matter, and for *in* sanitary purposes, presents an area of a considerably greater extent than can possibly be ascertained by the direct measurement of cesspools and drains.

Did you find it practicable to carry the drainage into the interior of this block of houses with the attainment of the advantages usually expected from back drainage?—The projected drainage shown on the plan by red lines, will best answer the question, especially if the eye be carried at the same time to the accompanying sections. The site, it may be observed, is peculiarly favourable for the development of the principles of sanitary engineering in their most extensive and complete application; the block forming a square island "insula," as the Romans would call it, with a good sewer running on each side, having sufficient fall, and at a most convenient depth. Although the instances of defective construction mentioned above are comparatively numerous, it will be remembered in how few instances it is necessary to take the lines of drainage under the houses, and with what facility the conveyance of the several house-drains is effected, so as to secure the greatest possible amount of acceleration to the flow; here the whole flow of the 282 houses is brought down to outlets, hence the amount must be nearly constant, and from the inclination given to the drains,

a stoppage becomes next to impossible, provided always, that the inlets are properly trapped. In stating thus much with regard to the block under consideration, no personal credit is intended to be assumed, on the contrary, the whole of the excellencies cited are to be ascribed to the development of principle so perfect in itself, and so strictly in accordance with physical laws, as to ensure a certain amount of success, even in the hands of the unskilful, although capable of perfection, directly in proportion to the skill employed in its adaptation. Mr. Cresy, jun.

Of the work proposed, what proportion would the earth work bear to the rest?—About one-sixth of the total cost.

For the action of the soil-pans, it was proposed to carry the water to the interior of this block of houses, what would be the expense in earth work or otherwise, of laying down the water apparatus separately?—The advantages of united works under one superintendence are so numerous and so great, that considerable difficulty exists in accurately estimating the precise money amount, the sum of the two estimated separately, so much exceeds their value taken conjointly, as to cause the estimater frequently to discredit his own results. In every locality the ratio would vary. In the case of the property now under consideration, the mains are laid in all the streets; but supposing the *whole work* to be commenced *de novo*, we should have 7 yards cube to each house, and 3,154 yards to the mains; to which must be added 700 yards super. of paving, and a 10 per cent. for superintendence and contingencies, thus:—

		£.	s.	d.
282 houses at 7 yards each	1*s.* 1*d.*	106	18	6
Mains 3,154 yards at	1*s.* 1*d.*	170	16	10
700 yards sup. paving	1*s.* 6*d.*	52	10	10
		330	6	2
Add 10 per cent.		33	0	7
Total		£ 363	6	9

Giving an *excess* of 363*l.* 6*s.* 9*d.* for the cost of mains, supplies, junctions, fittings, &c. may be taken as the same in either case.

What have you found to be the net gain by the combination of the two systems of works?—Hence we may consider that sum to represent the net gain by their combination.

Supposing them to be laid down and maintained in good action and repair for a term of years, what would be the expense of the complete distributory water apparatus, and of the house-drainage apparatus, and what would be the expense of the two combined, as compared with the existing expense of cleansing cesspools or keeping common house-drains in order, supposing the cesspools to be cleansed and the common drain to be kept properly in order?—I can but answer to these queries by putting in the estimates for the several works mentioned, subject to some observations, the whole question of estimates being here involved. Even in the most ordinary descriptions of work, great differences of opinion invariably are found among those skilful in the art of estimating, the value of raw materials, are constantly fluctuating; and although the average price of labour has not recently been subject to

Mr. Cresy, jun.

much variation, *its* quality must now be taken into account, there being at the present time, as many descriptions of labour as there are of material. Hence, *one* of the sources of discrepancy, observable between several contractors' estimates for the same work. The prices given in the accompanying estimates, would by a small contractor, about to execute the works for a dozen houses, be considered quite unremunerative. One in a large way of business contracting for 500 or 1,000 houses, would probably estimate considerably below these figures. I have endeavoured to pursue a middle course, relying where they would serve me, on the schedules of the Commissioners, jobbing contractors, and for such items as are not therein contained, on my own former experience in private practice. The Board of Health would render an immense service to the science of sanitary engineering by collecting and publishing detailed estimates of as many executed works as possible, both in the metropolis and the towns under its jurisdiction, as well as the prices of materials, as drain-pipes, gas-pipe, &c. An efficient check would be established on the contractors, and far greater accuracy in the estimates would be attainable.

From what you know of the metropolis, would not this be as difficult a block of houses as could occur, for combining drainage and water supply under one and the same management?—Undoubtedly; a glance at the plan will demonstrate this. Nevertheless, the system of combined drainage will be seen to be perfectly practicable, the cases in which the lines pass under houses are very rare, and even there, but little inconvenience to the inhabitants would be occasioned, as the back premises would alone be traversed, and this would be more than compensated by the immense advantage of a combined flow.

When the inhabitants understood the nature of the object in view, do you think that any reasonable difficulty need be apprehended in their allowing an officer of the Commission to come to the back of the houses from time to time to clear obstructions, and keep the apparatus in good order?—Having inspected a number of these houses myself and conversed with the inmates, I am enabled to state that they are all perfectly sensible of the advantages to be derived from the proposed measures, and most desirous, that as little delay as possible should occur in putting them into execution. I may add, that in all the inspections I have made, every facility has been afforded me, and all opposition has vanished before an explanation of the nature and extent of my inquiry.

Might such a block as the Hanway-street block be drained irrespective of any question as to the general drainage of the metropolis?—Most unquestionably; the outfalls for that block are already provided by existing sewers, and the whole operation thereby involved is completely independent of all other considerations.

What have you observed to be the result of the system of laying down main lines irrespective of house-drainage and *vice versa?*—No practical general result can be obtained from so doing; the whole system must exist in the mind of the engineer as a whole, otherwise he pursues his course blindly, to his own discredit and the great pecuniary injury of his employer.

Supposing an order given to execute the work, within what time

could the same be completed?—If sufficient strength were employed to carry on the whole simultaneously, in from six weeks to two months. Mr. Cresy, jun.

What is your view of the practicability of carrying out the work by the system of compulsory orders served on the occupiers of the several premises?—I should imagine, from the experience I have had under the Commissioners as well as in private practice, that such a mode would be utterly impracticable. One man would be likely to begin, his next neighbour would demur; another would, as I have actually found to be the case, request to delay the works until he could communicate with his landlord in the West Indies.

If the drains are properly laid, would there be any accession soever for additional supplies for flushing purposes?—None whatever; the flow being constant, no deposit can possibly take place.

What will be the expense of the combined apparatus per house, under the old system, under the intermittent system, and under the constant system, respectively?—

—	Old system, brick-drains, and intermittent water supply.			Tubular drains, intermittent supply.			Constant supply by contract under Commission.		
	£.	s.	d.	£.	s.	d.	£.	s.	d.
House-drains and repairs . . .	6	7	0	3	4	7	1	19	8
Water-closet apparatus . . .	4	15	2	1	1	8	0	10	8
Kitchen sink	2	6	10	1	10	0	1	0	6
Yard drain	0	15	0	0	10	0	0	7	6
Water supply	7	19	2	4	19	1	0	19	3
Total . . £	22	3	2	11	5	4	4	17	7

This table exhibits the cost of draining, putting up water-closet apparatus, kitchen-sink yard-drain, and supplying water to a small house, under, 1st. The old system, with nine-inch brick-drains, lead cistern, Yorkshire stone sink, patent valve closet and its apparatus. 2nd. The modern system, with intermittent supply, slate cistern, stoneware sink, syphon-trapped closet, supposing the whole executed by a builder, for a single house. 3rd. The most economical plan, with the constant supply, requiring no cistern, and supposing a large number to be contracted for at once under the Metropolitan Commission.

In the Hanway-yard block what provision have you made for subsoil-drainage?—From that block being situated on comparatively high ground, with a good deep sewer in Oxford-street and Tottenham Court-road, carrying off all the upper drainage, it has been considered unnecessary to make any special provision for subsoil-drainage. In situations where this is required it is easily obtained by the use of pervious drain-tiles made of red earthenware and unglazed.

Within what period of time would any matter be completely removed from the site in question by the action of the drains you propose?—From the great acceleration of the flow induced by the concentrated back-drainage, I calculate that barely more than a minute would elapse, under ordinary circumstances, from the moment drainage matter enters the longest line till the moment it quits it.

Mr. Cresy, jun.

What district of the Metropolitan Commission is specially under your charge?—The eastern division of the Surrey and Kent district, comprising part of Bermondsey, Rotherhithe, Deptford, Greenwich, Camberwell, Peckham, Dulwich, Forest Hill, Sydenham, Lee and Lewisham.

Do you find in that district any of the water supplied to the houses to escape in waste?—A very large proportion; we have had no accurate gaugings taken, but noticing the time during which the water is on, the bore of the supply pipes, and the capacity of the cisterns and vessels provided for its reception, I should say that from two-fifths to one-half the quantity supplied is in many cases wasted.

What is the effect of this on the sites of habitations?—A most pernicious one; the wet soaks the whole of the soil, and has no means of escape, the subsoil being water-logged twice in twenty-four hours by the tide, and from the great portion of the district lying so remarkably low, it can only drain off for an hour before and an hour after low water.

Do you know of any other means of relieving this district than by pumping?—In the present state of science the engineer has generally the choice of several alternatives, but in this case he is so straightened as to have practically no choice at all. Either he must depress the outfall, which would be neither more nor less than lowering the bed of the Thames, or he must raise the district, burying the habitations one story, or he must have recourse to pumps. The whole Surrey and Kent district is, in fact, one vast "poldre," to use a Flemish term.

What do you find to be the expense incurred in removing by hand labour the deposit in the sewers after it has once been suffered to accumulate?—Under the Commission the cost varies with the nature and dimensions of the sewers from which it has been removed, but the book price for emptying and carting night-soil is 6*s.* 6*d.* per ton of 18 cubic feet.

Have you not in your experience found streets with a capacious sewer and few or no houses draining into it, and, on the other hand, house-drains laid down before any sewer is provided?—Frequently. I must acknowledge to have superintended such arrangements myself in private practice, although I fully confess the error of such a cause. But clients are sometimes deaf to the remonstrances of the architect, and in default of any permanent authority, the voice of interest can alone make itself heard. At the same time it must be stated that the legal difficulties and impediments to a scientific combination of main and house-drainage are so great, that a proprietor must have the wealth of Crœsus and the patience of Job, if he attempts to carry it out single-handed, although no practical difficulty exists.

Do you find the four-inch tubular drains keep themselves clean?—Whenever an opportunity for opening and examining them has occurred we have found them perfectly clean. Whenever a stoppage has taken place it has invariably arisen either from their not having a sufficient fall, or from the access to them not being sufficiently protected. In my own residence the whole drainage passes through a *three-inch* pipe, and I have hitherto experienced no inconvenience.

Do you find the junctions keep themselves clean?—Perfectly so. Of course I speak of those made with an easy curve; where they are at right

angles they frequently become obstructed; but under the Commission we never suffer them to be used. Mr. Grey, jun.

You were instructed by the Commissioners to examine and classify the plans for the drainage of the metropolis, did any of them make back-drainage a main feature of their projects?—So far as I at present remember, none of them; some may have introduced the subject incidentally in their memorials, but had it constituted a main element in their plans, I should have retained a distinct recollection of it, having been anxious in examining them carefully to select any striking point as a *characteristic* of the individual scheme.

Did the competitors appear to deviate from the old practice of draining down the centres of the streets?—I think none of them; certainly the great mass of the plans was entirely upon the old system.

What, in your opinion, would in general be the additional expense to the tenants incurred thereby?—Of course I can only reply to this question in a general manner, but should say that I have known instances of various kinds in which the excess of expenditure would vary from 35 per cent. up to 250 per cent., or twice and a half as much.

Did the competitors require additional supplies of water?—The great bulk of them did.

Did any schemes imply a combined system of water supply and house-drainage?—Most of them appeared to consider the water supply as of equal importance with the drainage questions; but they did not go into any detail on the subject, contenting themselves generally with indicating the source of water supply, and the mechanical means for raising it.

Did these schemes appear to evince a knowledge of the effects of concentrated house-drainage in reducing the size of main lines and the superfluous dimensions of the present sewers?—So far as the *internal* evidence of the plans themselves goes, to which alone I am enabled to speak, I can safely say that they did *not*. Of course it is distinctly understood that I speak solely of the plans, and am not in any way pronouncing upon the information possessed by the authors on these points.

Did you find any extensive advance upon the system which has hitherto regulated the metropolitan drainage?—No. Of course the proposals of many were on a much larger *scale* than anything hitherto done, but I think I may safely say that no principle remarkable for its novelty in an engineering point of view is to be found among them. I do not mean that neither ingenuity nor merit is to be found there, but that no new *scientific* principle is advanced by them, nor any novel practical application of an existing principle; hence I cannot say that any advance upon existing systems has been made, or rather there being at present nothing deserving the name of a system, that a scientific basis for one has been created by the competition.

Were the competitors men of extensive practice?—Among so large a number many well-known names are to be found, but not those who are considered as our principal engineers, and the greater portion were, comparatively speaking, unknown to fame; there were some, indeed, who were not engineers at all.

Mr. Gotto.

Mr. Edward Gotto examined.

1. Are you not assistant engineer to the Metropolitan Commissioners of Sewers?—I am surveyor to that Commission.

2. Before you entered into their service had you had much experience of house-drainage and tubular drainage?—I had, as town surveyor of Dover, in Kent.

3. Since you have been in the service of the Commission have you had further experience therein?—Yes, and have devoted a great deal of attention to it.

4. Have you also laid down drains at Dover, and seen much of other drains?—Yes, and, generally speaking, I have seen a great deal of tubular drainage in action.

5. Is your extent of observation of tubular house-drainage so wide that you think its success complete with regard to houses of different conditions?—My experience of the action of tubular pipe-drainage embraces a great variety of cases and circumstances, and I am satisfied as to its complete success when properly laid, with a constant supply of water, and of its superiority over brick drains.

6. Not only theoretically but practically?—Yes; that is to say, my observations have been quite sufficient to lead me to conclude that tubular house-drains, properly constructed, and with a sufficient domestic supply of water, will keep themselves clean. My opinion is, that the domestic supply of water need not for this purpose be increased beyond its present amount in ordinary cases, but this opinion presupposes that every house had a skilfully devised water-supply, efficiently connected under improved arrangements with the house-drains. A large proportion of the existing supply runs to waste, frequently causing dampness to the premises, without affording any benefit to the drains.

7. You have had occasion to prepare plans for blocks of houses at Goulston-street, Whitechapel; Church-lane and Carrier-street, St. Giles's; and Jennings-buildings, Kensington?—Yes, as surveyor to the Metropolitan Commissioners of Sewers.

8. What was the size of the block of houses you laid down at Goulston-street?—About 9 acres.

9. What size house-drains did you propose?—The private house-drains were proposed to be 4 inches in diameter, the houses being of the smaller class.

10. What is the smallest inclination you would allow in these pipes to keep themselves clean?—2 inches in 10 feet, or 1 in 60, and as much more as could be procured; but with an inclination of 1 in 60 they would keep themselves clear.

11. At that inclination what length of time would it take for a 4-inch pipe to discharge a day's supply of water; say 100 gallons?—If this quantity of water were already in a cistern of the ordinary elevation, and the 4-inch pipe communicating therewith, the water would be discharged in about two minutes after the pipes were full: the time the drain would take to fill, would of course be in proportion to its length, and the velocity of the water would depend also upon the pressure given by the elevation of the cistern. But under a system of constant supply, the water-pipes being always full and under pressure, the day's supply

would, if given all at one time, pass away as fast as it was so given, the rate of discharge then being according to the size of the supply-pipe. Mr. Gotto.

12. Supposing the surface-water to be discharged through the house-drains, at what rate would such a pipe discharge an hour of the heaviest rain-fall?—In about $5\frac{1}{2}$ minutes if it were all let off at once, or about 10 times faster than the rain came down: 2 inches in depth of rain in one hour falling upon the garden, roof, and yard of a house and premises, 15 feet in the front and 60 feet deep, would require a drain to afford the necessary and immediate relief capable of carrying off 15 gallons per minute, whereas a 4-inch drain, with an inclination of 1 in 60, or 2 inches in 10 feet, would discharge 162 gallons per minute, if it were kept full.

13. Take the Goulston-street block of houses: what is the largest size of drain?—Twelve inches in diameter: there are 402 houses, but several outlets were proposed, so that about 50 houses would drain through a 12-inch pipe.

14. As a general proposition, if the house-drains kept themselves clear, the mains should likewise keep themselves clear?—Yes; there is this greater reason for that, because, as every house-drain adds its volume of water to the stream in the main channel, it imparts an additional velocity, and these concentrated currents produce a scouring power in due proportion. Stoppages in tubular drains are usually discovered between the main-drain and the house, and arise from inadequate and improperly applied water-supply and insecure inlets. The chief obstacle to be overcome in house-drains is not the conveying away the liquid refuse, that is, the water-supply after it has served its domestic purpose, for this could be effected through a discharge pipe but little larger than the supply pipes; the difficulty is so to secure the several inlets, namely, the water-closet, sink, yard, and area grating, as to prevent the passage of solid matter, such as is difficult of suspension and so of removal in water. In one instance, the pipes on being taken up were found filled with ashes; in another, which I examined, the stoppage was occasioned by the ends of two pipes being placed about 12 inches apart instead of joined, and the intervening space roughly filled up with bricks on edge.

15. If you take 1 in 60 for house-drains, what would you have for small branch-drains that come into the sewers?—That depends on a variety of circumstances, but, generally speaking, the inclination of the outlet or lower end of the main sewer-pipes in a well-arranged system of drainage should not be less than 1 in 240, and as much more as possible; but large sewers, which form main lines, may be as flat as 1 in 1000, or 4 or 5 feet in a mile.

16. Then with the concentrated flow a less inclination would suffice?—This is found practically the case. We see it every day. The addition of more water to the stream in a sewer exercises a far greater influence on the velocity than does increasing the inclination; for a circular sewer-pipe *full* at the head will discharge four times the quantity of water discharged by the same sewer-pipe *half-full* at the head in the same time; and this last quantity will be again four times greater than that discharged by the same sewer-pipe *quarter-full* at the head, but if the quantity of water be not so increased in the sewer, such a discharge, velocity, and scouring power as that described above, cannot be

Mr. Gotto. attained, even though the inclination be increased to any extent. Hence, where waters are gathered together in one channel, the inclination becomes of secondary importance within certain limits.

This law is fulfilled in the abstract in open streams and rivers; they are steep at their source, and, as along their course their tributaries pour in, the inclination is in proportion diminished as the waters reach the outlet.

The practical inferences to be drawn from these data are—

1st. That the addition of an equal quantity of water to a sewer will impart very great scouring and cleansing power.

2nd. That in secondary and main sewers and pipes, inclination is not of so much consequence as it is in house-drains, where it is more under control, the effect being produced in the former by the addition of the collateral streams.

3rdly. That the inclination of 4-inch house-drains should not be less than 1 in 60; that of main sewer-pipes not less than 1 in 240; and that of main lines may be 1 in 1000.

17. You carried all these house-drains from the back, did you not, where you could?—Yes; these plans were designed on that principle of drainage.

18. Do the smaller house-drains keep themselves clear, according to your experience, while the larger one would be choked?—They do: in very large house-drains, the water being spread over a large surface, and there being but little hydraulic depth, the water has but little power to remove obstacles; this is so in tubular drains, but obtains to a still greater extent in brick drains; the reverse is the case in contracted channels of a tubular form and uniform bore.

19. You are aware that in common drains there is a great deal of soakage, and a consequent loss of water?—In brick drains I have found the sewage matter act chemically upon the mortar joint, so as to produce rottenness, and the sewage soon penetrates through the bottom. One instance amongst many others occurred but recently, in which I had occasion to examine the drains of the St. Marylebone workhouse, where I found a well about 8 or 9 feet below an adjoining brick drain had been contaminated by its contents, and had been in consequence disused for some years.

20. Then there will be an economy in the actual discharge from a house in this way, and a concentration of force, if it be sufficient to keep not only the drains but the mains perfectly clear?—Yes. There will be required a less quantity of water to be supplied to a house to keep its drain clear, if that drain be small, than if it be large, and the force of the water will be more concentrated and calculated to bear upon any obstacle requiring to be removed, and by judicious arrangements these streams may be made to act upon the flow in the main channel so as to ensure their perfect and permanent self-action.

21. Then, in point of fact, according to your experience, if properly constructed, an additional supply beyond the present domestic supply of water will not be needed?—Not for keeping the drains clean; and, taking into consideration the quantity and nature of the matter to be removed from houses by means of drainage, I am confirmed in the opinion that the average quantity of water now found to be supplied to

Mr. Gotto.

the ordinary class of houses is sufficient for that purpose, if judiciously applied. For it is estimated by Bousingault, and confirmed by Liebig, that each individual produces ¼ lb. of solid excrement and 1¼ lbs. of liquid excrement per day, making 1½ lbs., or 150 lb. of semi-liquid refuse per 100 individuals from the water-closet. But there is other refuse resulting from culinary operations to be conveyed through the drains: the whole may be about 250 lbs. for 100 persons. Now 3 gallons or half a cubic foot of water will carry off 1 lb. of solid fæces through a 6-inch pipe with an inclination of 1 in 10, and 720 gallons per day would suffice to remove the domestic refuse from a building containing 100 persons, that is about 7 gallons for each person. It has been stated by water companies that each person on the average was supplied with 13 gallons per diem, but a number of cisterns gauged in St. Marylebone and Paddington showed only 3 gallons as having been so supplied. (*Vide* House of Lords Report, 1840, on Water Supply, questions 385, 394, 486.)

In my opinion, if 6 gallons of water, or 1 cubic foot, for each person per diem were supplied and advantageously passed through properly laid house-drains, with a sufficient inclination, of well-judged materials and size, it would suffice not only to keep the drains clean, but to carry off the sewage produced in the houses. It is not here intended to affirm what quantity of water is necessary for domestic use, but simply for the purposes of efficient drainage; but any additional quantity that might be deemed requisite for baths, wash-houses, &c., would be so much more benefit to the drains; and when it is remembered that a day's supply of water can be carried off by a 4-inch drain in two minutes after the pipe has become filled, as has been already shown, there will be no question as to the capability of a 4 or 6 inch house-drain to take off the additional quantity supposed above.

A prospective estimate of 25 gallons each person per diem was advanced in the First Sanitary Report, 1847, p. 53. But in my judgment not more than half that quantity would be used, for under the present intermittent supply the water passing through the house-drains varies from about 14 to 17 gallons per day per individual; and considering the enormous waste involved in that defective system, which would not be the case in a system of constant supply, it will be seen that these observations justify my opinion. An instance of the waste of water under the present system may be exemplified by an examination I have made of the flow of water through a pipe-sewer in Whitechapel. The water is on for about 1½ hour each day. There are about 900 gallons delivered into the five water-butts that supply the six houses, draining through a 9-inch pipe-sewer. The water-butts hold together 210 gallons, and all the rest runs to waste; 540 gallons of this is found by gauging to pass away through the drain. In another instance which has come under my notice, in John-street, Edgware-road, six houses having water-closets and cisterns are supplied by the West Middlesex Water Company. The cisterns together contain, before the water is newly turned on, 696 gallons, and after the water is turned off and they are full, 1086 gallons; the quantity therefore used and passing through the sewer in the two days of interval is 396 gallons; but on the water-day 1188 gallons passed through, so that there was 396 gallons used and 1005 gallons wasted in two days. The average quantity of water actually used in thi

Mr. Gotto. place is about 5 gallons per day for each person. In Park-place, St. James's, the Grand Junction Water Company supply nine houses (one a large mansion) with water, and during the hour of supply there passes through the 12-inch sewer-pipe from these houses 4320 gallons, while the quantity actually used per day and passing through the sewer when the water is not laid on is 3660 gallons, the quantity wasted being about as much as that used. It will be perceived that economy is out of the question, and that unbounded extravagance and waste pervade the system.

22. In respect to back drainage, what is the average length of drain per house compared with front drainage?—About one-third.

23. In the Goulston-street block of houses, what was the average distance gained by back over front drainage per house, and upon the whole number of houses?—That block of houses is favourable to the back drainage, and the average gain per house by such an arrangement over the ordinary plan of laying the drain through each house into the main in the sewer-pipe in the street or place would be about 35 feet, and the approximate saving in length for the whole block would be about 14,000 feet.

24. In that instance did the back drainage enable you to gain a fall which you could not through the front?—In that instance the advantage in improved inclination would be in proportion to the length of drain saved by adopting the arrangement of back drainage. For instance, if the sewer-pipe were in the street 9 feet deep, the house-drain passing from the water-closet at the back through the building into the sewer, the length of the house-drain would be, say 45 feet, whereas, if the sewer-pipe passed along the back close to the water-closet and other inlets, the length of house-drain would be about 10 feet, according to the annexed plan, and therefore the advantage in the inclination is evident, and that advantage is acquired just in the part of the system where it is most required, namely, in the single drain, which has to do its own work unaided by the combined force of other streams. There are, however, other circumstances under which the foregoing reasoning would not apply, as in the main sewer in the front of a row of houses, previously receiving a large amount of drainage, which, being more than an equivalent for inclination, maintains a sufficient velocity with a less fall, passing the fronts of the houses at such a greater depth as would afford a better inclination by the longer drain through the house, than by the shorter drain discharging at the back into the sewer-pipe, which must rise more steeply on account of receiving less drainage, till at the upper end it might be but a few feet only below the surface. This will occur in a great many instances; and leads to the conclusion that no general rule can be laid down for back drainage that will dispense with the exercise of judgment and skill on the part of well-qualified officers.

25. How much quicker will the refuse be discharged by back drainage than by the front?—The removal of refuse from a house will be accelerated both by the shorter length of drain secured by back drainage and the improved inclination attained thereby. It would be carried from the house about four times faster than if it has to pass through the house into the sewer-pipe in front.

26. Suppose you got an outfall for this block of houses, and the table

to drain to was equal; what would be the difference in point of time with front and back drainage?—The extra length of drains required if they were to pass through the houses I estimate at about 14,000 feet; and a day's supply of water for 402 houses, at 100 gallons each, would be 6700 cubic feet. This quantity would be discharged through 4-inch pipes, laid at an average inclination of 1 in 40, and half-full at the head, in about 36 hours; but it is to be observed, that this total length is made up of the several distinct lengths from each house, through all which the sewage would be passing at the same time, and therefore the difference in point of time can only strictly be said to be that required for the passage of the sewage from one house through its extra length of house-drain. Mr. Gotto.

27 and 29. Will you compare the frictional surface of back tubular drainage, not only with front tubular drainage but with front drainage on the old plan by brick drains and brick sewers?—To calculate the frictional surface of the three descriptions of drainage set forth in this question, and give the four comparisons required, would involve laying out the several systems, and occupy myself and assistants many days. I therefore confine the answer to a single house, of which there are 402.

Assuming the average proportion of length as in former questions in reference to this block, namely, as 10 feet is to 45 feet, the comparative frictional surface will be as follows:—

Back drainage, 4-inch pipes . .	126	superficial feet.
Front drainage, 4-inch pipes . .	545	,,
Ditto, 9-inch brick drains . .	1272	,,

28. To produce the same effect, supposing you have the minimum supply of water for back drainage, what is the additional supply of water required to overcome the additional amount of friction by front drainage?—Confining the question to the house-drains, no additional quantity of water would in such a case as that assumed in the foregoing questions be required to produce the same effect in front drainage as is produced in back drainage.

The question requires much consideration, and the result would vary materially in every different case. Assuming all other points of comparison to be similar, if the inclination be such as is required for house-drains, or 1 in 60, this inclination, together with the minimum supply of water, would generate an accelerating force by which the sectional area of the water would be decreased through the whole length of the pipe in proportion to the increased velocity; therefore the moving power in the lower end of the pipe will be made up by such increased velocity to the momentum which obtains at the upper end of the pipe, by the increased sectional area of the water, so maintaining nearly an uniform motive power throughout the 45 feet of pipe required for front drainage as it would through the 10 feet of pipe here supposed as the length required for back drainage: the accelerating force overcoming the additional amount of friction.

29. [See No. 27.]

30. What would be the total area or evaporating surface of filth in this block of houses, if, in addition to cesspools, there were drains from all the houses on the old plan of brick drainage?—The same reasons oblige me to confine this answer within the limits of the preceding; and

Mr. Gotto. supposing the whole length of all the pipes to be half-full, or giving the maximum, the result will be thus:—

Cesspool (say 3 ft. × 3 ft.) . . .	9 feet superficial.
Drain, 9-inch diameter	34 ,,
	43 ,,

31. What is the additional quantity of water you estimate would be required for the Goulston-street block of houses, to keep the house-drains clear and the sewers clear, if they were drained on the old plan? Or what would be the gain in water in this block of houses by increasing the speed as well as lessening the friction?—I feel that the experiments and observations hitherto made on the quantity of water required to move bodies in brick drains are not sufficient to justify my giving a very explicit answer to this question; but, comparing the 4-inch pipe-drains of a house laid at 1 in 60, and 10 feet long, with a 9-inch brick drain at an inclination of 1 in 40 and 45 feet long, as far as present experience justifies the comparison, I am of opinion it would require three times the quantity of water to produce the desired effect in the 9-inch brick drains.

32. What do you estimate the expense per house of tubular front drainage and back drainage?—Referring again to the plan of a house in New Castle-street, Whitechapel, the estimate for *back* drainage (not including the cost of water-supply) would be as follows, if the pipes were made and the work were done by contract under the Commissioners of Sewers:—

Water-closet Apparatus and Drain.

	£.	s.	d.			
Emptying and filling up the cesspool .	0	12	0			
Digging, filling in, &c., for 8-feet pipe-drain, at 4*d*.	0	2	8			
Making good to walls and floor of water-closet over drain, at 3*d*. .	0	2	0			
8 feet run of 4-inch pipe, at 3*d*. . .	0	2	0			
Laying ditto, at 2*d*.	0	1	4			
Extra for junction	0	0	4			
Fixing ditto	0	0	2			
Water-closet apparatus complete, with stool-cock	0	10	0			
Fixing ditto	0	2	0			
10 per cent. for contingencies . .	0	3	6			
				1	16	0

Yard Sink and Drain.

	£.	s.	d.
Digging and filling-in for 6 feet run of 4-inch pipe, at 4*d*. . . .	0	2	0
Making good yard surface, 6 feet, at 3*d*.	0	1	6
6 feet run of 4-inch pipe, at 3*d*. .	0	1	6
Carried forward . .	0	5	0

Mr. Gotto.

	£.	s.	d.	£.	s.	d.
Brought forward . .	0	5	0	1	16	0
Laying ditto, at 2*d*.	0	1	0			
Extra on junction	0	0	4			
Fixing ditto	0	0	2			
Double trap, with sink . . .	0	3	0			
Fixing ditto	0	0	8			
10 per cent. for contingencies . .	0	1	0			
				0	11	2

Kitchen Sink and Drain.

	£.	s.	d.	£.	s.	d.
Stoneware kitchen sink	0	4	0			
Fixing ditto and making good . .	0	1	6			
9 feet of 2-inch drain-pipe, at 2½*d*. .	0	1	10½			
Laying ditto, at 2*d*.	0	1	6			
Digging for ditto, at 4*d*. . . .	0	3	0			
Making good paving, &c., at 3*d*. .	0	2	3			
10 per cent. for contingencies . .	0	1	6			
				0	15	7½
Cost of *back* draining one house, including water-closet, and kitchen and yard sinks				£3	2	9½

Estimate for the *front* tubular drainage of the same house in this block, exclusive of cost of water-supply apparatus, if the pipes were made and the work were done by contract under the Commissioners of Sewers:—

	£.	s.	d.	£.	s.	d.
Emptying and filling up cesspool .	0	12	0			
Digging and filling in to 45 feet of 4-inch pipe, at 4*d*. . . .	0	15	0			
Making good to walls and floor of water-closet and room of the house, 30 feet, at 3*d*.	0	7	8			
45 feet of 4-inch pipe, at 3*d*. . .	0	11	3			
Laying ditto, at 2*d*.	0	7	8			
Extra for junction	0	0	4			
Fixing ditto	0	0	2			
Water-closet apparatus, with stool cock	0	10	0			
Fixing water-closet	0	2	0			
Relaying 15 yards of carriage-way, paving, &c., at 1*s*. 6*d*. . . .	1	2	6			
10 per cent. for contingencies . .	0	5	0			
				4	13	7
Digging and filling for 8 feet of 4-inch pipe, at 4*d*.	0	2	8			
Making good yard surface, &c., 8 feet, at 3*d*.	0	2	0			
Carried forward . .	0	4	8			

Mr. Gotto.

	£.	s.	d.	£.	s.	d.
Brought forward	0	4	8	4	13	7
8 feet 4-inch pipe, at 3*d*.	0	2	0			
Laying ditto, at 2*d*.	0	1	4			
Extra on junction	0	0	4			
Fixing ditto	0	0	2			
Double trap, with sink	0	3	0			
Fixing ditto	0	0	8			
10 per cent. for contingencies	0	1	3			
				0	13	5
Kitchen sink and drain, as in the last estimate				0	15	7½
Cost of *front* draining one house, including water-closet and kitchen and yard sinks				£6	2	7½

These estimates are only for the works of private improvement, and do not include the cost of the main sewer-pipe in either case: with this addition the total estimates would be as under:—

Back Tubular Drainage.	£.	s.	d.	Front Tubular Drainage.	£.	s.	d.
14 ft. 6 in. for 6-inch pipe-sewer, and making good to yard surface at 2*s*.	1	9	0	14 ft. 6 in. frontage for 6-inch pipe-sewer, and making good carriage-way paving at 2*s*. 10*d*.	2	1	1
Private house drainage (see foregoing estimate)	3	2	9½	Private house drainage (see foregoing estimate)	6	2	1½
Total	4	11	9½		8	3	2½

33. What is the additional expense of front drainage where it is requisite to cut through flooring, &c.?—The extra cost involved by front drainage of cutting through the floor, and making good the same and the carriage-way in the front of the house, upon which these estimates are founded, would be 1*l*. 8*s*. 2*d*.

34. What is the expense per house and district upon the old system, with brick drainage running through to the front of the house, with brick sewers in the streets, &c.?—The expense for the drainage of one house, with cesspool and brick drains into the sewers, I estimate thus—

	£.	s.	d.
Digging, filling, &c., for 50 feet of 9-inch drain from sewer to cesspool, and sink in yard, at 7*d*. per foot	1	9	2
Making good floors and walls through houses, 35 feet, at 4*d*.	0	11	8
Making good carriageway-paving, 15 yards, at 1*s*. 9*d*.	1	6	3
Carried forward	3	7	1

Mr. Gotto.

	£.	s.	d.
Brought forward	3	7	1
Digging and carting 3 cubic yards of earth from cesspool, at 3*s*.	0	9	0
50 feet run 9-inch barrel-drain, at 1*s*. 4*d*. . .	3	6	8
25 feet superficial reduced brickwork for cesspool, at 10*l*. 4*s*. per rod	0	18	9
Riser and seat to privy	0	6	5
Brick trap in yard	0	12	6
Yorkshire stone sink in kitchen, with bell-trap and pipe into drain	1	12	0
10 per cent. for contingencies	1	1	6
Cost of drainage of one house under the old plan, exclusive of main sewers	11	13	11

This estimate does not include the expense of main brick sewers, such as would formerly have been constructed, the whole expense for which, in the block of houses of 9 acres, alluded to before, would be 3755*l*., or 7*l*. 8*s*. 6*d*. per house for the use of the main sewer alone. The total cost would be—

	£	s.	d.
House-drainage	11	16	11
Main sewers	7	8	6
	£19	5	5

35. What is the gain in the water-power, and what is the gain in the expense of drainage?—There would be a saving of about 38,400 gallons of water per day on 400 houses, and a gain on the expense of drainage of about 5680*l*. As to the water-supply, as I have already stated, 6 gallons for each person per diem would be sufficient for keeping skilfully-constructed house-drains clear; and supposing eight persons to each house, the average in this block would require 48 gallons per house; while it is my opinion 150 gallons would be required to keep drains of such a house clear if constructed of brick according to the Metropolitan Buildings Act, and as is the case for the most part throughout the metropolis where any house-drainage exists—the tubular pipe-drainage substituted within the last few years being the exception to that which generally prevails. The detail-estimates sufficiently explain and justify the gain in the cost given above of back-drainage over the old plan of brick drains and sewers. Indeed it has been found to be altogether impossible to drain the lower description of houses in the metropolis upon the old plan, on account of the enormous expense; and this is the reason that all the poorest localities, where drainage appliances are most required to remove the rapidly-accumulating filth resulting from the overcrowded state of the dwellings, are entirely destitute of such important requisites of health and comfort. The same reason may in a great measure be assigned for the prominence such places hold in the Registrar-General's repeated reports of deaths, and why they are so conspicuous in times of cholera.

Mr. Gotto.

36. In this Goulston-street plan you not only contemplated the removal of all cesspools, but also the substitution of water-closet apparatus?—Yes. The sanitary improvement of that place, as well as of others upon which I have reported from time to time, embraced the substitution of a water-closet apparatus for the cesspool.

37. Have you any idea of the additional quantity of water the water-closet apparatus would require for this block of houses?—The water now running to waste under the present imperfect supplying apparatus would more than suffice for the use of the water-closets. In the instance before given three-fourths of the water run to waste during the time of supply.

38. What is the average consumption per house where supplied from butts, the supply being on alternate days?—The average quantity of water actually consumed per house is about 57 gallons in the lower neighbourhoods, such as Whitechapel, and where each house contains 10 persons on an average. This is ascertained by selecting a number of houses where the water-butts are emptied before the next supply fills them. But the houses in such places have not all cisterns; most of the inhabitants procure their water from the stand-pipe in stone jars, many others have pails and kettles, but few have cisterns or water-butts.

39. Did you find that the butts were not emptied on the second day?—103 water-butts and cisterns out of 141 which have been examined in this place were not emptied before the next supply came in.

40. Did you find the foundation of the houses very damp there?—The lower floors of the houses thus imperfectly supplied with water, and having no drainage, are very damp, especially where stand-pipes are used to deliver the water. In some places the yards are completely flooded in consequence. And this dampness, besides aiding in the production of sickness, hastens the decay of house property, and is thus the cause of much permanent damage.

41. Do you think that the damp was greater than could be accounted for by the mere rainfall?—There can be no doubt of it; the overflow from water-butts often passes into the cesspools, where there are any, and penetrates to the house foundation: it is periodical, certain, in large quantities, and always in one place, and hence is sure to accomplish the work of destruction, though perhaps for a time unnoticed. For this reason the subjects of water supply and drainage are inseparably connected: water should only be very cautiously administered where no drainage exists; and where houses are supplied with water there should be drains to carry it away, and both should be under one superintending jurisdiction.

42. Where the houses were drained could you find an average discharge of water?—I have had several opportunities of making such observations. In a case before alluded to at Goulston-street, 6 houses, standing on an area of 223 square yards, are supplied with 900 gallons of water by the New River Company daily, for about $1\frac{1}{2}$ hour, into 5 water-butts, containing each 7 cubic feet, or together 210 gallons. The average discharge here through the 9-inch stoneware drain, during the time the water is being delivered, is 330 gallons per hour, or 495 gallons during the time of supply, and about 6 gallons per hour during the remainder of the day. This was only the ordinary flow from the houses, and in fine weather.

Observation No. 2.—About 380 houses, draining into a 12-inch pipe laid along the towing-path of the Regent's Canal, near the Caledonian-road :— Mr. Gotto.

Date.	Total Discharge in 24 hours.	Discharge per House in 24 hours.	Greatest Flow per hour.	Least Flow per hour.
	Gallons.	Gallons.	Gallons.	Gallons.
1850. Thursday, January 10, not a water-day . .	18,927	50	4200 (From 1 to 2 P. M.)	252 (From 6 to 7 A. M.)
Friday, January 11, water-day . . .	26,412	85	12,600 (From 10 to 11 A. M.)	252 (From 6 to 7 A. M.)
Saturday, January 12, water-day . . .	39,669	104	12,600 (From 7 to 8 A. M. from 3 to 4 P. M.)	186 (From 6 to 7 A. M.)
Monday, January 14, not a water-day . .	14,169	40	3150 (From 9 to 10 A.M.)	140 (From 6 to 7 A. M.)

The greatest depth of water in the 12-inch pipe during these experiments was 3 inches, but little more than one-third of its sectional area.

43. As a general rule, may it be said that nothing is sent down the soil-pans that the water will not carry away, and that the more the junctions are the greater will be the rapidity of the discharge ?—I have found in my experience of tubular house-drainage that what usually passes down the water-closet will be conveyed away if there be an adequate supply of water. When stoppages are discovered in house-drains having a sufficient supply, they are generally found to arise from the improper construction of the drain, irregularity of the inclination, imperfect joints, &c., although the matter accumulated is very frequently hair and grease, which would have, however, readily passed away, had the obstructions not been left in the drain itself at its construction ; this appears from the upper and perfect part of the drains being quite free from any appearance of such matter, and the point of stoppage being at the imperfect part. If junctions be properly moulded and skilfully laid in, the contributions of water they discharge will accelerate the velocity of the united current in the main sewer-pipe, and therefore all the branches from the various parts of the house should be short, and united to the principal house-drain as soon as possible. But if they are laid in at right angles, each junction tends rather to impede the velocity by discharging its stream across the direction of the current in the house-drain. The same principle, of course, obtains with regard to main sewer-pipes and brick sewers.

44. What would be the additional expense for cisternage, for Goulston-street block of houses, to give the locality a constant supply ?—The expense of constructing a water-tank at a sufficient elevation, and of a capacity to contain two days' supply of water for this block of houses, would be about 160*l*. The water would be supplied by the New River Company, and the mains always full and charged. Several years would elapse before any great and extensive works of improved water-supply could be completed ; and the plan here suggested and detailed in my Report upon Church-lane, St. Giles's, of dealing with blocks of houses in the poorest neighbourhoods, and pro-

Mr. Gotto. viding them with small systems of constant water-supply connected with efficient drainage, cannot fail of affording the desired relief in the mean time, and that with a considerable saving over the present intermittent and wasteful practice. Moreover, the mains and domestic distributing pipes and apparatus would be adapted to and ready for the general improvements contemplated whenever they should be carried out; and if this plan were adopted in such places, immediate relief might be afforded where it is most required, and those very extensive works of distribution would be in progress, which would otherwise occupy many years, if their commencement be delayed till the source of metropolitan water-supply be decided.

45. What would be the rate of additional expense of construction at other places to make the present intermittent supply of water a constant supply?—In Church-lane and Carrier-street, St. Giles's, there are 110 houses. I have prepared plans and estimates to supply these houses with water in the manner before described. The water-tank and mains of fire-clay would cost 262*l.* 10*s.*, or 2*l.* 7*s.* 7*d.* per house, that is, provided the water-mains were laid in the same trenches and at the same time as the main sewer-pipes, for the digging and reinstatement of the paving, which form the largest items in the expense, would be thus in a great measure saved. The expense per house for the service-pipe to the ground-floor, stop-cock, stool-cocks, and tap to the sink, would be about 16*s.* 6*d.*; this, with the cost as above of general works, would be 3*l.* 4*s.* 1*d.*

46. State what is the average size and cost of pipes?—The water-mains of fire-clay would be required about 3 inches in diameter (at 3*d.* per foot) for such a block of houses and Goulston-street, and the house-service 1 inch in diameter, at a cost of 1½*d.* per foot. These prices are given, assuming that the manufacture of pipes for this purpose would be carried on upon a principle of economy commensurative with the contemplated demand.

47. Will you state the extra supply of water which might be consumed by a proper system of surface-cleansing by jet?—This will depend upon the pressure under which the water is delivered and the frequency of plugs, but it appears, from experiments, that the average quantity of water required for street cleansing after this manner would be about 1 gallon for every superficial yard of paving each time.

48. What is the expense of that mode of cleansing, compared with that of scavenging?—It is estimated that 100 yards of paving can be cleansed by the hose and jet for 2¼*d.* each time; and if this be done every day, it would amount to 14*d.* per 100 yards per week. It should be observed that the plan of washing the mud from the streets into the sewers involves the expense of removing it from them; for it is found that the heavy matter from the carriage-ways is the most difficult of removal from the sewers, concreting on the bottom, and frequently requiring to be brought to the surface by hand labour. Beyond this item in the total expense, for which no accurate estimate can be made, there is another in sweeping and scraping solid matter, which cannot be removed effectually from the surface by the use of water only. It is found also that constant sweeping, by hand-labour or machine, during the day, is the best means of preventing the accumulation of mud in streets. This process also, to a very great extent, supersedes the

necessity and expense of watering the streets, on account of all dirt being removed as soon as it is created, and before it can become dust. Where there is a constant and rapid accumulation of filth, there should be as constant a means of removal, and this cannot be the case with the hose and jet. It is a matter of daily experience that sweeping will cost per 100 yards per week— Mr. Gotto.

Labour	$5\frac{1}{2}d.$
Brooms, &c., and superintendence, about . .	1
	$6\frac{1}{2}d$
To this must be added the cost of watering when it is required . . . . The charge is about 2*d.* per yard for the season of about half the year.	$7\frac{3}{4}$
Total cost per 100 yards per week for sweeping and watering	$14\frac{1}{4}d.$

There is no item in this estimate for cartage, since the value of the manure is found to be equivalent to it.

49. Have you, in the course of your experience, found that, as a general rule, there is any substantial difficulty in the way of back-drainage?—I have not hitherto found any insurmountable mechanical difficulties in the way of constructing back-drainage. On the other hand it will be seen, by what has been already advanced, that generally speaking it possesses in practice many advantages over any other description of house-drainage. *First,* in point of economy, being on the average about *half* the cost of tubular drainage passing through each house to the sewer in front, thus bringing this important sanitary improvement within the reach of owners of the lowest description of house property. *Secondly,* it is more efficient; carrying off the refuse and filth from the houses much faster than by front-drainage, on account of the shorter length of drain required, while, for the same reason, there would be less chance of stoppages taking place, and less cost of repairs. It is found in practice desirable on this account to make house-drains as short as possible. *Thirdly,* it is more convenient, there being no necessity to disturb the floors and foundations of houses, either for the first construction or during repairs. But while there are frequent applications for back-drainage in preference to other more expensive plans made by owners of house property appreciating the advantages before enumerated, there are also many who delay the improvement of their property rather than execute the work upon such a principle. The difficulties to be encountered and provided against, in adopting this arrangement as a general principle, require serious consideration. *First,* as to one person's right of draining through his neighbour's house; *secondly,* as to individual liability to cleanse and repair drains laid under such circumstances. It is found that in this way considerable annoyance, trouble, and expense often fall upon a person, the drain of whose house is stopped in consequence of the carelessness (sometimes wilful) of his neighbours in sending down the drain matter it was never intended to convey. *Thirdly,* some inconvenience may be anticipated in apportioning the expense of construction of the main sewer-pipes in back-drainage, for, the size of the pipe at the back of the house at the lower end may be 15 inches, and gradually decreasing in size till

Mr. Gotto. it may be 6 inches at the back of houses at the upper end. Thus, while more expense will be incurred on the premises of the one than the other, yet the benefit would in either case be equal. These objections to the system may, however, be obviated by efficient arrangements under the authority of the Act of Parliament carried out by a properly organized staff of inspectors of house-drainage, to ensure and preserve its proper action.

50. Would not one and the same person suffice for keeping soil-pans in order, for the removal of dust, and for other work of a like description for keeping all clean?—Yes; and under well-devised arrangements the same inspectors might at the same time attend to the delivery of the water-supply, especially as under an improved constant water-supply the establishment of turncocks would be dispensed with, or their labour in a great measure lightened.

51. So far from an indisposition to having this cleansing carried on, is it not the fact that people themselves are willing to pay for it?—I have found it so, among the lower classes especially. It is stated in a Report presented by myself to the Commissioners of Sewers—"that in some parts of Whitechapel there are occupants of 60 rooms using three water-closets, and a poor women had undertaken to keep them clean for 1*d*. per week per room, producing 5*s*. per week; and it is stated to have been cheerfully and punctually paid. There were offers made at the time by tenants of rooms in Church-lane to pay the same weekly sum per room to keep a common privy cleansed. On this part of the property, consisting of 10 houses, this arrangement is adopted. A man is employed to cleanse the yards, privies, &c., and receives 1*s*. per day and his lodging." This plan is adopted in many other of the lower neighbourhoods of London, and, if matured, might be made far more easy and economical.

52. Would it not naturally fall, in the division of labour, to men in the position of turncocks also to be occupied in cleansing by the use of the jet, and keeping the taps, and other such portions of the distributary water apparatus, in order?—It would; and if the drainage, water-supply, paving, and building works, were placed under one jurisdiction, separate districts might be assigned to separate officers in respect of all these particulars.

53. Did you not contemplate and propose, in a Report, that this apparatus should be put down and kept in order by a contract for some years?—Yes, for five years.

54. What is the total cost per house per week that you estimate all this might be done, in a state of things in which there would be no accumulations, and in which water would simply be required to remove all out of sight?—All the cleansing works of paved yards, and attention to stoppages in drains, taps of water-supply, &c., would cost about one penny per house per week. I estimate that one person would attend to about 400 houses.

55. According to the ordinary rate of flow, what is the greatest length of time that any decomposing refuse could be removed from such a block of houses as the Goulston-street block?—About eight minutes, the greatest length of sewer-pipe being 860 feet.

56. At what rate would that flow have been in the main sewer?—The average rate of flow in the sewer would be about 24 inches in a

second; but this would vary at almost every part of the day in proportion to the quantity of water used. Mr. Gotto.

57. What length of time would the refuse remain in the drain of the kind of houses you have been speaking of?—But a very few seconds, the length of the drains under this plan being very short.

58. What would have been the expense of the earth-work in laying down this drainage, as calculated in your estimate?—

713 cubic yards digging	£62	7	9
458 cubic yards digging	40	2	1
2294 cubic yards digging	200	15	4
Total cost of digging for the main-sewer pipes	£303	5	2

59. What was the proportion of that expense to the whole?—Just half the cost of the whole work.

60. Supposing you had to lay down the water-supply apparatus separately from drainage and with distinct earth-work, what would be the additional expense?—For only the water-mains, about 210*l*.

61. If one man were on the spot to take care of the drains and sewerage, would it not be desirable to intrust to him the supervision over the water-apparatus?—Yes, very desirable: indeed, these two works, being inseparably connected with each other, ought to be under one control and management.

62. Would he not be the man to apply to immediately to procure speedy relief on occasions of fire breaking out in the neighbourhood?—He would; and being intimately acquainted with the water-apparatus, and having under his control the keys and plugs, much of the delay and confusion now universally experienced on such occasions would be obviated, while property and life would be in greater security.

63. Would not this plan tend to a reduction of fire risk upon this block of houses; and, if so, to what extent?—It is difficult to say to what extent, owing to the difference existing among the fire-offices in the manner of fixing the class of the risk: some offices would not take such property as this at all, but I am of opinion that the risk would be considered as reduced one-half by the adoption of such contemplated facilities for extinguishing fire.

64. Supposing the case of new buildings being contemplated, would it not be a desirable regulation that the surveyor or officer of the Sewers Commission, who would have to see to the putting down of the drains, should also see to the regulations as to party-walls being completely and effectively complied with?—Certainly; and very great inconvenience is now felt in consequence of these works being under different superintendence; the same person might do both with very little additional labour, trouble, and expense; and such an arrangement would materially facilitate the exercise of that control which ought to be had over the construction of drainage and water-supply works. It frequently happens that improperly constructed drains are surreptitiously introduced into the sewers from newly built houses, the existence of which the surveyor of sewers is ignorant of.

65. In laying down the distributory water apparatus at the backs of houses, would it not often avoid crossing areas, and thereby avoid exposing the pipes to frost?—It would diminish that inconvenience

Mr. Gotto. very much, since none of the pipes outside the house need be exposed: by this arrangement the water-apparatus would be shortened as well as the house-drainage, and it would be desirable to lay them down together and in the same trenches.

66. What extent of area do you think one man could keep in good cleansing order?—About 10 acres, if he had to keep the courts and alleys clean, as well as attend to the drainage and water-supply.

67. How much is the existing charge for such an amount of work?—About 200*l*. per annum for emptying the cesspools, without taking into account the expense of surface-cleansing and removal of solid refuse, for calculating the cost of which there is no data.

68. In respect to the amount of supplies in cisterns in this block of houses, did you notice circumstances to show the effect of exposure of water therein?—In many cases there was a very large deposit in the bottom of the cisterns, partly owing to the soot and dust, and partly arising from the foulness of the water supplied: the uncovered cisterns have uniformly more filth accumulated in the bottom than those which are covered, and are cleansed more often, in some cases once a fortnight, and even once a week: the water in these butts and cisterns is often frozen in the winter, and in the hot summer weather is deprived of its coolness, and, being stagnant, putrifies: from the information of the residents in this locality it is said to smell offensively in the summer.

69. In respect to the water distribution, will not this laying on of water, on a system of constant supply as contemplated, have the advantage of occasioning not only less exposure, but greater uniformity of temperature?—There need be no exposure in a properly laid constant supply of water, for the receptacles would be done away with; and by laying in the service-pipes at the backs of houses, as is here contemplated, the pipes would not as now pass along the area-wall above ground: it is most frequently in this part that the water freezes and the pipes burst at the ensuing thaw. For the same reason there would be an uniformity of temperature in the water, which could not be obtained by the present system.

70. Give the total expense of the apparatus for the distribution of water, distinguishing the expense of service-pipes per house, of the waste or return pipes from each house not properly called drains, and the expense of what would be called branch-mains?—Under a constant-supply system no waste-pipes would be required, and the digging and paving would be saved by using the same trench as the drain.

Estimate for water-supply apparatus to the house, shown on plan under the constant system.

	£	s.	d.	£	s.	d.
15 feet of stoneware service-pipe, and laying, at 6*d*.	£0	7	6			
Stop-cock and fixing at the main	0	3	6			
Stool-cock and fixing to water-closet	0	2	6			
Joint at the water-main	0	0	4			
				0	13	10
For the branch-main, 15 feet of 3 in. stoneware main, and laying, at 8*d*.				0	10	0
				£1	3	10

Mr. Gotto.

71. State also the expense of each water-closet apparatus laid down complete?—

The water-closet apparatus laid down complete would be	£0 12 0
Emptying and filling up the cesspool, about . . .	0 12 0
	£1 4 0

72. Also the expense of soil-pans supplied from waste-pipes?—The expense of soil-pans is 7*s.* 6*d.* each.

73. Also the expense of building common necessaries where a new one is necessary?—A public water-closet, constructed of hollow brick, similar to the accompanying plan, would cost about 10*l.*

74. Were you not directed by the Works Committee to examine and analyse the cost of production of drain-pipes and water-pipes; will you put in a table of the comparative expense of the present price of such materials, and the prices at which you reported they might be contracted for: include also in the table the present price of manufacture of stoneware pipes of the first quality, and the prices at which earthenware pipes might be manufactured, according to your report, of such quality as would serve for a water distribution?—I received instructions from the late Commissioners to make some investigations as to the cost and manufacture of earthenware pipes. With this view arrangements were made for moulding and burning some pipes in the improved kilns of the Ainslie Tile Company. The result of these experiments is contained in the following table, showing the quantity of material, and the cost of each part of the production. The total shows what may be called the neat prime cost of the goods at the kiln: a large percentage should of course be added for profit, carriage, &c. &c.

Cost at which tubular drain-pipes were manufactured in these experiments.

Size of Pipes, inches in diameter.	Materials.		Cost of Materials, Labour, and Burning, per 1000 Feet.					
	Clay.	Coals, 1 cwt. to a Ton of Clay.	Cost of Clay, say at 7*s.* per Ton, including Royalty, Digging, &c.	Labour in Pugging, &c., at 2*s.* per Ton.	Labour in Moulding, carrying to Drying Shed, and Attendance during Drying.	Cost of Coals, at 20*s.* per Ton.	Extra for Management, Kiln-rent, Waste, Labour, Packing, and Drawing the Kiln.	Total Prime Cost per 1000 Feet in the Field.
	Ton. cwt. lbs.	Cwt.	£. s. d.	s. d.	£. s. d.	s. d.	£. s. d.	£. s. d.
5	4 0 20	4	1 8 0	8 0	1 0 0	4 0	1 10 0	4 10 0
6	5 15 0	$5\frac{3}{4}$	2 3 0	11 6	1 8 9	5 9	2 3 1	6 9 4
$7\frac{1}{2}$	6 16 70	$6\frac{3}{4}$	2 9 9	13 7	1 14 2	6 9	2 12 0	7 16 1
$8\frac{1}{2}$	8 18 50	9	3 2 5	17 10	2 4 8	9 0	3 7 0	10 0 11

Each process of the manufacture is capable of very considerable improvement in respect of expense, time, and quality; but to bring this manufacture to maturity would require larger pecuniary resources and undivided attention. It will, however, be seen, by the following table, that, with the present incomplete and imperfect appliances, a very large

Mr. Gotto. reduction may be anticipated in the cost of these descriptions of goods, a result of the very highest importance, contemplating the immediate and large demand for sanitary purposes.

Table contrasting the prices of tubular drain-pipes.

Fifty per cent. is here added to the prices in the foregoing table, for profit, carriage, &c. &c.

Size of pipes, inches in diameter.	Lengths.	Red earthenware pipes if made by contract.			Red earthenware pipes at the present sale prices.			Stoneware glazed at the present sale prices.			Average Gain: On red earthenware pipes if made by contract over the present prices.			Average Gain: On red earthenware pipes if made by contract over glazed stoneware pipes.		
		£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.	£.	s.	d.
5	Per foot	0	0	1½	0	0	5	0	0	6	0	0	3½	0	0	4½
	Per 1000 feet	6	15	0	20	16	8	25	0	0	14	1	8	18	5	0
	Per mile	35	12	9	110	0	0	132	0	0	74	7	3	96	7	3
6	Per foot	0	0	2¼	0	0	6	0	0	7	0	0	3¾	0	0	4¾
	Per 1000 feet	9	14	0	25	0	0	29	3	4	15	6	0	19	9	4
	Per mile	51	4	4	132	0	0	154	0	0	80	15	8	102	15	8
9	Per foot	0	0	3¾	0	0	9	0	1	0	0	0	5¼	0	0	8¼
	Per 1000 feet	15	1	6	37	10	0	50	0	0	22	8	6	34	18	6
	Per mile	79	11	10	198	0	0	264	0	0	118	8	2	184	8	2

These experiments were carried on under many disadvantages and hindrances, calculated to increase most materially the ultimate cost of the production; and, from my experience, I am of opinion, that for the expenses exhibited in the table, and under more favourable circumstances, such as would obtain in a large and convenient establishment, pipes could be produced from common clay of sufficient strength for water distribution. One of the most important advances towards this state of perfection is that of submitting the pipe, when half dry, to an extreme pressure between two polished iron surfaces, whereby a density of substance and truth of form is attained, which imparts a superiority over the best description of glazed stoneware yet produced. A machine for effecting this purpose has been constructed and patented by Messrs. Burton and Sons, engineers, Blackfriars.

75. Allowing fifty per cent. on your estimated prime cost of production by the present improved methods, what would the production of such pipes at such prices reduce your estimate for the water-supply of the block for the supply of which you were called on to estimate and report on?—About one-half.

76. What would be the total price, in each case, per house, of the reduced estimate for pipes, assuming that a constant supply of water would be provided, and cisterns be thus rendered unnecessary?—

Estimate for laying on water to one house under the present intermittent system.

	£	s.	d.
24 feet super slate cistern, and fixing	£1	16	0
45 feet supply-pipe	2	5	0
8 feet service-pipe	0	6	8
10 feet waste-pipe	0	10	0
	£4	17	8

Mr. Gotto.

Estimate for laying on water to one house under the contemplated constant system of supply.

See page 11 . . . . £0 13 10

77. What was your estimate of the expense of constructing gully-shoots on the improved construction, compared with the expense of former construction in Westminster and the City?—The price of gully-shoots was—

	£.	s.	d.
As constructed in the City	12	16	10
As constructed in Westminster district, in 1839....	7	17	6
Ditto ditto ditto in 1845....	4	4	11
Ditto at present of 9-inch stoneware pipes	3	17	0½
Ditto at present of 6-inch stoneware pipes	3	5	4
As they may be constructed of red earthenware pipe by contract under the Commissioners	1	10	3

78. In carrying out the improved drainage-works and waterworks, brickwork would, of course, be needed for man-holes, for the formation and arching over of culverts, &c.?—Brickwork will always be required in drainage, for the more important lines of sewers, and other works.

79. Your investigations as to the cost of producing drain-pipes will, of course, be applicable to the production of hollow bricks?—Under the direction of the late Commissioners I had some hollow bricks burnt at the time of making experiments on pipes.

80. Did you examine and analyse the prime cost of the production of hollow bricks?—I did, and the following table shows the neat prime cost at which hollow bricks could be made by contract under the Commissioners by the use of improved machinery and kiln:—

Prices at which Hollow Bricks could be made under the Commissioners, by the use of Improved Machinery and Kiln.

Size.	Quantity of Material used per 1000 feet.		Cost of Materials, Labour, and Burning, per thousand feet.						
	Clay.	Coals at 1 cwt. per ton.	Cost of clay and digging, at 2s. per ton.	Labour in working, at 2s. 6d. per ton.	Labour in making, at 1s. per ton.	Cost of coals, at 20s. per ton.	Double duty.	Extra for management, kiln-rent, waste labour, packing, and taking out of the kiln, and contingencies.	Total cost per 1000 feet in the kiln.
	tons cwt. lbs.	cwt. lbs.	£. s. d.	£. s. d.	s. d.	s. d.	s. d.	s. d.	£. s. d.
4 by 4	6 13 0	6 73	0 13 4	0 16 7½	6 8	6 8	10 6	9 4¾	3 3 2½
5 .. 5	7 15 2	7 85	0 15 6¼	0 19 5	7 9¼	7 9¼	10 6	10 11	3 11 10¾
6 .. 6	8 18 6	8 104	0 17 10	1 2 4	8 10½	8 10½	10 6	12 6	4 0 11
8 .. 8	12 19 3	12 54	1 4 11	1 11 2	12 5¾	12 5¾	10 6	17 4¾	5 8 11¼

81. Will you give a tabular return of the comparative cost of solid brickwork and of hollow brickwork per superficial yard?—

Mr. Gotto.

TABLE contrasting the PRICES of SOLID BRICKWORK at the contract price under the Commission, namely, 11*l.* per rod, with Brickwork of Hollow Bricks, if made by contract under the Commission, including the duty in both cases.

Description of Labour, Materials, &c.	Quantities.	9-inch solid brick-work, laid in mortar.	8-inch hollow brick-work, laid in mortar.	Gain by using 8-inch hollow, instead of 9-inch solid brick-work.
		s. *d.*	*s.* *d.*	*s.* *d.*
Bricks	Per sq. yard.	2 10¼	..	..
Labour, Carriage, &c. . . .	,,	1 2	0 8	..
Mortar	,,	0 10	0 6	..
Cost of hollow bricks, if made by contract under the Commission	,,	..	1 5½	..
Total .	,,	4 10¼	2 7½	2 2¾

Mr. Rawlinson prepared the following table of the relative cost of hollow and solid brickwork, and, having carefully considered it, I find it agree very nearly with my own experience :—(*See* p. 195.)

82. Are you aware of any experiments with respect to the comparative strength of these materials?—Such experiments have been made, and, as a general result, it is found that hollow bricks are one-third stronger than solid bricks of the ordinary size. The following table will show the degree of strength given to pipes subjected to the pressure before described as compared with unpressed pipes :—

EXPERIMENTS to try the STRENGTH of PIPES made by the NEW MACHINE, March 2, 1849.

Number of Experiments.	Marks.	Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Length of Pipe, in inches.	Weight of Pipe, in pounds.	Breaking Weight in pounds pressure per inch.	Altitude in feet.	Rolled or not.	Glazed or not.	Remarks.
1	H.	2·812	·469	20·68	8·75	420	970·2	Rolled	Unglazed	Smith's fine clay.
2	H.	2·87	·471	22·37	9·25	380	877·8	,,	,,	
3	H.	2·87	·471	22·37	9·25	280	646·8	,,	Glazed	
4	N.	2·68	·472	21·0	7·75	180	415·8	Unrolled	Unglazed	Smith's fine clay.
5	N.	2·7	·473	21·5	7·89	170	392·7	,,	,,	
6	N.	2·69	·471	21·3	7·9	200	462·0	,,	,,	
7	E.	2·75	·468	21·5	8·12	140	323·4	Rolled	,,	Smith's coarse clay.
8	A.	2·75	·468	22·31	8·25	270	623·7	,,	,,	
9	B.	2·75	·468	22·37	8·25	260	600·6	,,	,,	
10	M.	2·75	·5	21·37	8·25	160	369·6	Unrolled	Glazed	Smith's coarse clay.
11	M.	2·75	·468	21·37	8·5	120	277·2	,,	Unglazed	
12	M.	2·73	·475	21·47	8·36	110	254·1	,,	,,	
13	..	2·375	·656	23·12	12·25	660	1,524·6	Rolled	Glazed	Smith's fine clay
14	..	2·375	·656	22·75	12·25	360	831·6	,,	,,	
15	..	2·375	·630	24·12	12·75	500	115·5	,,	,,	

Averages of the above.

								Difference per Cent.	
1 to 3	2·8506	·470	21·806	9·083	360	831·6	Rolled	96·36	Fine clay.
4 to 6	2·69	·472	21·26	7·846	183·3	423·5	Unrolled		
7 to 9	2·75	·468	22·06	8·206	223·3	515·9	Rolled	71·79	Coarse clay.
10 to 12	2·743	·481	21·403	8·37	130	300·3	Unrolled		
13 to 15	2·375	·6473	23·33	12·416	506·6	1,170·4	Rolled	..	Fine clay.

Mr. Gotto.

ANALYSIS of the CUBIC CONTENTS, AREA, HEIGHT, and COST PRICE of HOLLOW TILE and SOLID BRICK.

No.	Description of Materials.	Thickness of Tile in section.	Dimensions of Common and Hollow Bricks. Inches. Length.	Breadth.	Thickness.	Relative cost per thousand.	Number of bricks in one square yard.	Number of square yards in one thousand.	Thickness of Wall in inches.	Net cost of Bricks in one square yard.	Cost of Labour to set one square yard.	Cost of Mortar to set on square yard.	Cost of one square yard set complete.	Remarks.	Extra cost per yard if set in cement.	Cost of one square yard set complete in cement.	Cube inches of space in one square yard.	Cube inches of solid in one square yard.	Weight in lbs. of one Brick.	Weight of one thousand solid and hollow bricks.	Weight in lbs. of one square yard.
		In.				£. s.				s. d.	d.	d.	s. d.		d.	s. d.				T. c. q. lb.	
1	Common brick .	..	9	4½	3	1 10	96	10½	9	2 10¼	9	9	4 4¼	Wall one brick, or 9 in. thick .	9	5 1¼	..	11,664	8½	3 15 3 16	816
2	Common brick for partitions. . .	..	9	4½	3	1 10	48	21	4½	1 5	5	5	2 3	Wall one brick, or 9 in. thick .	5	2 8	..	5,832	8½	3 15 3 16	408
3	Hollow brick, square on section	1	12	9	9	5 15	12	83⅓	9	1 4½	8	6	2 6¼	Wall half-brick, or 4½ in. thick.	6	2 8	7,056	4,608	27¼	12 3 1 6	327
4	Hollow ditto . .	1	12	8	8	4 15	13½	74	8	1 3½	8	6	2 5½	Wall one hollow brick, or 9 in. thick. . . .	6	2 6½	5,832	4,536	23	10 5 1 12	310½
5	Ditto	¾	12	6	6	3 10	18	55¾	6	1 3¼	8	6	2 5¼	Wall one hollow brick, or 8 in. thick. . . .	7	2 1½	4,320	3,456	14	6 5 0 0	252
6	Ditto	¾	12	5	5	3 0	21¾	47½	5	1 3	8	6	2 5	Wall one hollow brick, or 6 in. thick. . . .	8	2 5	3,132	3,348	10¾	4 15 3 26	233¾
7	Ditto	¾	12	4	4	2 5	27	37	4	1 2½	8	6	2 4½	Wall one hollow brick, or 5 in. thick. . . .	9	2 10	1,944	3,240	7½	3 6 3 24	202
8	Hollow ditto partition tile set on edge	½	12	6	2	1 10	18	55¾	2	0 6½	4	2	1 0½	Wall one hollow brick, or 4 in. thick. . . .	4	1 4½	864	1,728	7	3 2 2 0	126

N.B. One square foot of tile one inch thick is taken at 10lbs. weight.

r. Gotto.

COMPARATIVE STRENGTH of MATERIAL on each square Inch of the Sectional Area of Pipes.

Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Sectional Area of Pipes.	Breaking Weight in pounds on each square inch of the Sectional Area.	Altitude in feet on each square inch of the Sectional Area.	Rolled or not.	Remarks.
2·8506	·470	4·903	73·41	169·6	Rolled	Fine clay.
2·69	·472	4·688	39·2	90·41	Unrolled	
2·75	·468	4·732	47·2	109·07	Rolled	Coarse clay.
2·743	·481	4·872	26·7	61·61	Unrolled	
2·375	·6473	6·146	82·5	190·6	Rolled	Fine clay.

EXPERIMENTS to try the STRENGTH of RED EARTHENWARE PIPES made by the PATENT PIPE MACHINE, July 18, 1849.

Number of Experiments.	Mark.	Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Length of Pipe, in inches.	Weight of Pipe, in pounds.	Breaking Weight in pounds pressure per inch.	Altitude in feet.	Rolled or not.	Remarks.
1	A.	2·75	·5	23·125	7·437	175	404·25	Rolled	Sound to 120 lbs.; then the water came through in several places.
2	,,	2·75	·5	22·312	6·875	135	311·85	,,	
3	,,	2·625	·5	20·375	6·25	110	254·10	Unrolled	Sound to 100 lbs., and then same as No. 1.
4	,,	2·687	·5	20·5	6·25	Unsound	..	,,	
5	B.	2·687	·5	23·5	7·5	105	242·55	Rolled	
6	,,	2·687	·5	22·25	7·25	Unsound	..	,,	
7	,,	2·625	·5	21·187	6·624	95	219·45	Unrolled	
8	,,	2·625	·5	17·562	5·5	50	115·50	,,	
9	C.	2·812	·5	23·25	6·562	185	427·35	Rolled	
10	,,	2·625	·5	21·5	6·062	155	358·05	Unrolled	
11	D.	2·75	·5	23·875	7·624	125	288·75	Rolled	
12	,,	2·687	·5	23·687	7·624	120	277·20	,,	
13	,,	2·687	·5	21·625	6·875	95	219·45	Unrolled	
14	,,	2·562	·5	21·25	6·562	100	231	,,	

Averages of the above Pipes, &c.

A.	2·75	·5	22·719	7·156	155	358·05	Rolled	40·9 difference per cent.
,,	2·656	·5	20·437	6·25	110	254·10	Unrolled	
B.	2·687	·5	22·87	7·375	105	242·55	Rolled	38·9 ,,
,,	2·625	·5	19·37	6·062	77·5	167·47	Unrolled	
C.	2·812	·5	23·25	6·562	185	427·35	Rolled	19·3 ,,
,,	2·625	·5	21·5	6·062	155	358·05	Unrolled	
D.	2·718	·5	23·78	7·624	122·5	282·97	Rolled	25·6 ,,
,,	2·624	·5	21·5	6·718	97·5	225·22	Unrolled	

Mr. Gotto.

COMPARATIVE STRENGTH of MATERIAL on each square Inch of the Sectional Area of Pipes, July 18, 1849.

Bore of Pipe, in inches.	Thickness of Pipe, in inches.	Sectional Area of Pipes.	Breaking Weight in pounds on each square inch of the Sectional Area of Pipes.	Altitude in feet on each square inch of the Sectional Area of Pipes.	Rolled or not.
2·75	·5	5·105	30·3	70·1	Rolled.
2·656	·5	5·	22·	50·82	Unrolled.
2·687	·5	5·007	20·9	48·4	Rolled.
2·625	·5	4·9	15·8	34·2	Unrolled.
2·812	·5	5·203	35·5	82·1	Rolled.
2·625	·5	4·9	31·6	73·	Unrolled.
2·718	·5	5·1	24·	55·4	Rolled.
2·624	·5	4·8	20·3	46·9	Unrolled.

83. Were not experiments directed to be made as to the strength of hollow bricks of different kinds?—They were; but various circumstances have prevented me completing those experiments in detail.

84. Were there not experiments directed to be made as to the comparative flow of water through pipes made more exact by compression?—They were, and the result showed that the rolling or pressure gave one quarter more velocity to the water.

HYDRAULIC EXPERIMENT, showing the delivery of Water through red unglazed Pipes, compared with glazed stoneware.

Description of Pipe.	Inclination.	Time to discharge 25 Cubic Feet.	Height of Water above Top of Pipe.	Diameter of Pipe.	Cubic Feet per Hour.	Velocity per Second.	Stoneware compared with the Red Pipe.
		m. s.	Inches.	Ft. In.		Feet.	
Glazed stoneware .	1 in 60	2 0	3	0·24	750·	4·9	..
Red-ware rolled, B.	,,	2 18	3	0·23	652·17	3·72	5 to 4·34
Red-ware, B. . .	,,	2 48	3	0·23	535·71	3·06	5 to 3·57
Red-ware rolled, D.	,,	2 28	3	0·23	608·1	3·47	5 to 4·
Red-ware, D. . .	,,	2 46	3	0·23	542·1	..	5 to 3·61

The Pipe in the above experiment was fully charged.

EXPERIMENTS with the same Pipe running half full.

Glazed pipe . .	1 in 60	4 16	Water level with head of pipe	..	351		
Red-ware rolled, B.	,,	5 58	,,	..	251	..	5 to 3·52
Red-ware, B. . .	,,	6 34	,,	..	228	..	5 to 3·24
Red-ware rolled, D.	,,	6 15	,,	..	238	..	5 to 3·39
Red-ware, D. . .	,,	7 15	,,	..	206	..	5 to 2·93

85. From this evidence it appears, then, that by these means an increase of velocity of one-fourth may be given to the general sweep of water and the rate of discharge of all fœcal matters from beneath the site of towns?—Yes, that is so.

Mr. Gotto. 86. What would be the price per foot of 4-inch pipes of the improved manufacture (with compression)?—Four-inch red earthenware pipe could be manufactured in large quantities for about $1\frac{1}{2}d.$ or $2d.$ per foot.

87. Will you give any points of information you possess as to the run of water through drains or sewers in the district of the East London Company on the days when the water is laid on as compared with the days when the water is not laid on?—I have not had an opportunity of furnishing this information.

Mr. John Morris, examined.

Mr. Morris. 1. What position do you hold?—I am surveyor of highways of the parish of Poplar, and hold an appointment under the Metropolitan Commission of Sewers.

2. The Metropolitan Sanitary Commissioners are desirous of ascertaining what extra quantity of water will be required beyond the common supplies for house-drainage under the improved system. Have you not within your district a block of houses which has been drained with tubular drains?—Yes; between 20 and 30 blocks of houses.

3. Will you give a specimen of one?—Yes; there is a block of 12 houses which has been drained with 4-inch glazed pipes leading to a 6-inch drain in the road. These houses are supplied by the East London Water-works, on the intermittent system, and the drains have been 12 months in action.

4. Have you the opportunity of seeing that they discharge all matter coming into them by the ordinary quantity of soil-water so as to keep the drains quite clean?—Yes; and yet the water is only thrown into the soil-pans not regularly laid down, so that they are under that disadvantage, and still they answer, although one of the drains was stopped for want of water.

5. Has each house a soil-pan apparatus?—Soil-pan and trap, but still it is imperfect, inasmuch as the water has to be thrown down, and where water has to be taken to it it does not get attended to.

6. Is this common drain laid under the road?—Yes; a 6-inch drain was laid down under my direction in the road, and has acted perfectly.

7. Under the old method would there not have been a brick drain carried through the house?—Yes; there would have been a 9-inch brick drain, and that would inevitably have been stopped. In a house of my own a brick drain has been twice cleansed in the course of seven years, and I have just laid down a tubular drain instead of it, as I found the water was settling under the foundation of the house.

8. Then a 9-inch drain, which was required by the Building Act, would inevitably have been stopped up, while the improved kind with the same supply of water kept clear?—I may observe as respects the old brick drains that the smell is so bad in some houses that the doors and windows were compelled to be opened in consequence of the brick drains being under the floors.

9. Have you tried these new 4-inch tubular house-drains, laid down and kept in action in your district for such a time and under such varied

circumstances as to leave you no doubt of their applicability to all the drainage within it?—I have introduced them into some houses for the trustees of the parish of Poplar, with water-closets, and have received no just cause of complaint. In every instance where I have applied it I found the system answer extremely well where a sufficient quantity of water has been applied. Mr. Morris.

10. What are the expressions of the occupiers in relation to the new tubular drainage?—Expressions of great satisfaction: they have now no smells on the premises, and that they feel better in health.

11. In the particular block of houses you mentioned, what would be the expense of draining from six houses by one 4-inch pipe, as compared with the prices of draining laid down upon the old method? —About two-thirds less.

12. And there is the saving of not only the length required for carrying the drain through the front of the house to the centre of the street, but also a saving in the distributory apparatus for the water?—Yes.

13. Then this double plan just exhibits the different modes of drainage under the old system and that of the Metropolitan Sewers Commission. Can you describe the sanitary effects of this improved drainage? —There is no comparison between them; so decided is the advantage of the improved method, as before stated.

14. What are the observations of the householders as to the effect of the new drainage?—The answer has invariably been, that they and their families have been better in health; that they were formerly annoyed with smells and effluvia, from which they are now quite free.

15. Of course access to the backs of the premises for the repair of the drains or the service pipes for the distribution of water would be sometimes required. Have you experienced anything that would suggest to your mind that obstacles would be placed in the way of carrying out the system of drainage requiring such access?—I think not now, though there would have been formerly, the public not having had the experience of the improvement. I now think the public are prepared to go with the authorities in carrying out a complete system of back drainage.

16. Since the new drainage has been laid down has there been frequent occasion to go on the ground to examine it?—In this case there has been only occasion to go to it once for the whole year, and that was from the inefficiency of the water service.

17. And the whole district might then have been drained in the same way with as little relative demand for the inspection of back premises? —Yes, certainly. In one instance examination was requisite, and it was there found that rags had been thrown down and had got into the pipe, and further that very little water had been used, so that the stoppage was the fault of the tenant, not of the system. In this case the rain-water is carried away by a separate drain.

18. Have you considered what would be the advantage of a constant supply of water to these soil-pans?—Yes. It would in my opinion be a saving of one half the water, and the soil-pans and drains under the improved system be less liable to stoppage. I have found it answer very well where it has been applied to some of the water-closets.

19. Even supposing that there were no improvement in the population

Mr. Morris.

themselves nor in their habits, judging from the practical experience now obtained, would the occasional stoppages and obstructions resulting from carelessness or willingness, countervail the advantages of the system?—Certainly not. It has been applied to houses in Bromley St. Leonards. The inhabitants were poor Irish people, and not prepared by their habits for such improvements, but the plan answers, although the supply of water is very ill applied.

20. What sized butts are usually used for this poor class of houses?—4 feet by 2 or thereabouts, holding about 54 gallons.

21. From what you have observed of the population, do you think they use the whole of the contents of such a butt each day?—I think not so much.

22. Then if there were a constant supply of water carried into each house, there would not be more than 40 or 50 gallons used each day?—I think not.

23. It is stated that in the district about 200 gallons per house is pumped in three times a-week. Does it not follow from your statement of the sizes of the butts and the quantities consumed, that the greater proportion of the water now pumped into the district must be pumped to waste?—Yes; quite one half: all parties coincide in saying that full one half is now wasted.

24. Then you think that no additional quantity of water will be required in your district?—Not to the houses already supplied. All that is required is a different mode of application.

25. I believe there is very little paving in your district?—No; water would not be required for surface-cleansing, only for road-watering.

26. What amount of water do you use for that purpose?—28,000 gallons daily for the last season, which was 75 days, over a space of 50,000 yards, supplied at a cost of 5*s.* 6*d.* per 100 yards for the season, six months.

27. What is the largest single block of houses in your district drained by tubular drains?—150 houses, through a 6-inch earthenware outfall pipe not glazed.

28. Do all the houses drain into it?—They do; the drains are all old drains. The 150 houses drain into it, and about 10 of them have water-closets.

29. How is this earthenware pipe laid down?—It was laid down without any care, and connected with a 14-inch drain from the houses, and when it was accidentally stopped, from the pipe having broken, it was found that this drain had been in use for 17 years. All the drainage of this large block of houses must have been gradually carried into it in the course of years.

30. What is the quality of the water supplied by the Company in your district?—It is hard, and a sediment is produced in the cisterns; 2 or 3 inches of deposit collect in the course of a short time.

31. What do you pay for this supply?—About 4*s.* per room, and for a 3 or 4 roomed house about 3*s.* 6*d.* a room.

32. Supposing the water were properly distributed, would any additional supply be required?—I think not for the East of London.

33. Have you noticed the effect of these permeable drains when there is no rainfall?—I have seen the water under the basement-floors of houses, arising partly of the waste of the water pumped in.

34. Therefore the waste at present is worse than useless?—Yes; for it only creates dampness in the yards and houses. Mr. Morris.

35. Will you give the contrast in prices of the construction of new impermeable drainage with the permeable drainage, and contrast that with what it will be before the change of system?—I applied some years since to the old Sewers Commission to drain a district in the Tower Hamlets, and for main drains alone for some 600 or 700 houses they asked 4000*l.*; that would have been at a rate of charge, with the private drains, altogether, of nearly 10*l.* a house; under the present system not only could the main drains be made, but the private impermeable drains also, complete, at 5*l.* a house.

36. By the new system is not the smell from the drains prevented in houses?—Yes; I have inquired of the tenants of the house where the drains have been reconstructed under the new system, and they inform me the smell is abated.

37. Then you agree with other surveyors as to the best observations which have been made with regard to the waste of water?—They coincide precisely with my own views.

38. Do you think that as much water as 200 gallons per house can be required, even where a portion of the water would be needed for water-closets or for road-watering?—I think not.

39. Then you concur in the opinions expressed upon these points by other assistant surveyors, that if the water pumped in were properly distributed under a system of constant supply, properly applied to an appropriate system of tubular drains, no additional quantities would be needed either for domestic use, or for the flushing of drains or sewers, or for road-watering?—The present quantity would certainly be ample.

Mr. J. Medworth examined.

Mr. Medworth.

Have you not been engaged in carrying out experimental trial-works under the Metropolitan Commission of Sewers?—I have.

Among other trials have you tried the quantity of water requisite for soilpans of different forms and constructions?—I have.

What is the least quantity of water required to carry away the soil from, and keep clear, a syphon-pan as at present constructed?—I have found a gallon on an average sufficient.

How much more is required for pans of other construction?—Sometimes, even with repeated flushes, there was a difficulty in keeping them clear, but it mainly depended on the way in which the water was admitted to the inner surface of the pan.

Then, with any quantity, some pans will not keep themselves clean? —In some pans, as constructed, it would require a very large amount of water to ensure a perfect clearance of the contents.

You have seen that the syphon-pans will keep themselves clean?—Yes: those of the commonest description—those made of brown stoneware.

Will you put in a diagram of the same?—This form of basin I have found to be the best kind, where there is no pan or dish used.

Mr. edworth. Have you not reason to believe that the form and application of the jet are still capable of improvement even for the action of the syphon-pan?—Yes.

Would it not be better to admit the water in the front?—I think not. There is soil to be removed from the back of the basin, which would not be reached by the water if admitted in the front.

You think further experiments necessary for the proper adjustment of this?—Certainly. I think that the closet experiments at Greek-street were not carried out sufficiently, but I am satisfied that a gallon of water would suffice.

Then in a family of five persons 5, 6, or 7, or 10 gallons at most, would certainly be sufficient?—Certainly; particularly taking into consideration the quantity of slops that would be thrown down.

But is not the escape of gas more frequent from other pans than from the syphon-pan, as stated by Mr. Crump, of Derby?—Generally so.

But they require less water?—They do; half that is required for the syphon would be sufficient for the pan-closet.

Of course you would support the syphon-pan as most fitted for popular use?—Certainly; in consequence of the simplicity of the arrangements.

Both for cheapness and completeness?—Yes; except that in the syphon-pan arrangement there is a larger expenditure of water.

Among other things, were you not directed to try the flow of water from pipes of different constructions—some formed with pressure and some formed in the common way?—I was.

Did you not find that making the pipes smooth in the interior gave an increase of velocity of a third or fourth through a 3-inch pipe?—I did. These experiments were made with red-ware pipes, smooth, but not glazed.

What quantity of water would be discharged through a 3-inch pipe on an inclination of 1 in 120?—Full at the head, it would discharge 100 gallons in three minutes, the pipe being 50 feet in length. This is with stone-ware pipe, manufactured at Lambeth. This applies to a pipe receiving water only at the inlet, the water not being higher than the head of the pipe.

What would be the rate of discharge supposing the whole 100 gallons to pass through the drain from the back to the front of the house, say some 60 feet, and how soon would the water be clear of the premises?—All that could be swept away by 100 gallons would be discharged clear of the house at the rate I have already stated.

What would be the power of sweep?—Sufficient to remove any and even more than ordinary and usual semi-fluid deposit that is found in house-drains; that is, supposing the whole of the 100 gallons was to be discharged in the time stated.

What water was this?—Sewage-water, of the full consistency, and it was discharged so completely, that the pipe was perfectly clean.

At the same inclination what would a 4-inch pipe discharge with the same distances?—Twice the amount (that I found from experiment); or, in other words, 100 gallons would be discharged in half the time. This likewise applies to a pipe receiving water only at the inlet, and of not greater height than the head. In these cases the section of the stream is diminished to about half the area of the pipe.

Then a 4-inch pipe will discharge a 24 hours' supply of sewage-water a distance of 50 feet in a minute and a half?—Yes; taking the 24 hours' supply to be 100 gallons. Mr. Medworth.

Did you not try the force of this discharge with sand? and, if so, with what proportions?—Yes, with sand in proportion of from 1-16th to 1-40th the volume of the water, and the whole was entirely removed.

But the different construction of the pipe with respect to smoothness will make full a fourth difference in the rate of velocity?—Yes; with the red-ware pipes formed by pressure, the accelerated velocity due to regularity of form and smoothness of surface was one-fourth.

What pipes did you use in these experiments?—In some experiments, including those previously referred to, we used red-ware pipes, but principally glazed stone-ware pipes were used in the experiments at Greek-street.

Have you not found that exactitude in the make is more important than the glaze?—Yes, the exactness of form and ACCURACY OF JOINT are very important, so that the pipes may run into each other and form a complete cylinder. As an instance of the importance of exactness of joint, I had a case happen at one of my houses within the last few days. The tenant complained of the stoppage of the drain from the closet, &c. Upon sending a man to make an examination, it was found that the trap contained several oyster-shells, and one had been discharging into the drain, where it was arrested by an imperfectly formed joint.

Then you found on experiment that this exactness of form expedited the discharge full one-fourth?—Yes. As before stated in the case of the red-ware pipes.

Have you tried the effect of junctions on the main?—Yes.

Suppose two of these 4-inch pipes were joined, what would be the velocity gained by junction into a main?—At an inclination of 1 in 60 the increased discharge would be in some cases nearly double; that is, the single pipe will deliver 84 gallons per minute; the addition of another similar 4-inch pipe will increase the discharge to 162 gallons per minute. The discharge will vary, dependent upon the position of the junction on the main line; the further from the head or inlet, the greater the discharge.

Before these experiments were made, were there not various hypothetical formulæ proposed for general use?—Yes.

What would these formulæ have given with a 3-inch pipe, and at an inclination of 1 in 100? and what was the result of your experiments with the 3-inch pipe?—The formulæ would give 7 cubic feet, the actual experiment gave 11½ cubic feet; converting it into time, the discharge according to the formulæ, compared with the discharge found by actual practice, would be as 2 to 3.

Or, putting it into another form, if there were a given quantity of detritus or fæces to be removed, it would, according to the formula, require nearly double the quantity of water that was found absolutely requisite in practice?—The proportionate discharges were found to be as 2 to 3, therefore the power required would be in those ratios.

How would it be with a 4-inch pipe?—The formula would give about 14·7 cubic feet per minute, whereas practice gave 23 cubic feet per minute.

Take the case of a 6-inch pipe of the same inclination?—The result,

Mr. Hedworth. according to Mr. Hawkesley's formula, would be $40\frac{1}{5}$ cubic feet per minute; from experiment it was found to be $63\frac{1}{2}$ cubic feet per minute.

Will you convert that into time, and consider the 6-inch pipe as a small branch sewer? Within what time would 100 gallons be discharged at the same inclination over 50 feet?—It would be discharged in 15 seconds.

That is to say, that the actual experiments prove how much less water can be made to suffice than these formulæ prescribe?—Precisely so.

Then with respect to mains and drainage over a flat surface, the result of course becomes of much more value as the difference proved by actual practice increases with the diminution of the inclination?—Certainly, to a very great extent. For example, the tables give only 14·2 cubic feet per minute as the discharge from a pipe 6 inches diameter, with a fall of 1 in 800; practice shows that, under the same conditions, 47·2 cubic feet will be discharged.

Will you give an example of the practical value of this when it is required to carry out drainage works over a very flat surface?—An inclination of 1 in 800 gives only 14 cubic feet per minute according to theory, while, according to actual experiment, and with the same inclination, 47 cubic feet are given.

Then this difference may be converted either into a saving of water to effect the same object, or into power of water to remove feculent matter from beneath the site of any houses or town?—It may be so.

And also the power of small inclinations properly managed?—Yes. For example, if it was required to construct a water-course that should discharge say 200 cubic feet per minute, the formula would require an inclination of 1 in 60 = 2 inches in 10 feet; whereas experiment has shown that the same would be discharged at an inclination of 1 in 200, equal to $\frac{5}{8}$ths of an inch in 10 feet, thus effecting a considerable saving in excavation, or a smaller drain would suffice at the greater inclination. The practical importance of knowing the precise value of inclination is incalculable, and will be found so in laying down drainage for a flat district, or through loose and wet soils, where the extra labour in excavating the last few inches in depth to obtain a given level will often exceed in cost as many feet. I have frequently met with such cases. To name one, I will state that, during the progress of a sewer contract I had in 1842 for the Commissioners of the Holborn and Finsbury district, the depth of the trench was about 9 feet, and perfectly dry; the cost for labour was 8*d.* per cubic yard; the invert of the sewer, according to the levels given by the surveyor, required to be about 6 inches lower, and this proved to be in a running sand of the most troublesome nature, and cost me at the least 10*s.* per yard in the removal before the invert could be laid down.

Then all these experiments tended to the reduction of the quantity of water necessary to effect good cleaning, and removal of soil and matter held in suspension?—It would.

And render more manageable works of drainage with comparatively small power, and make it more efficient and much cheaper, with properly constructed machinery?—Yes.

Mr. Hawkesley's tables are, I believe, taken as embodying the current and most recent formulæ before the institution of the trial-works,

and were in practical use by engineers, &c.?—They were of the highest authority; but the results I have given have been verified by a variety of experiments. Mr. Medworth.

What junctions did you try?—A 3-inch junction into a 4-inch main, and a 3-inch junction into a 6-inch main.

Would it not have been the practice formerly in making a junction of two 3-inch pipes to have made the outlet a 6-inch pipe?—That, I believe, would have been the general practice.

Will you state what you have found the practical results of these trial-works to be on this subject?—One very important result arrived at is the fact of having ascertained the precise value due to *inclination*, as has been before shown. This was a point not practically known to writers upon hydraulics, if we may judge by the theories promulgated. Again, the *actual* practical discharge of water through pipes of different sizes has been determined upon, together with the effects that junctions on to a *main line* have. The system of projecting the results of the experiments by diagram suggests a ready method of calculating the discharge due from cylindrical water-courses. This has the authority of the late "Trial Works Committee," and is, I believe, recommended in their Report recently laid before the present Commissioners. These are a few amongst the many practical results obtained from the trial-works.

What are the practical deductions from these effects in respect to junctions?—The practical effect is a considerable degree of velocity in the discharge of water.

An increase of velocity in the discharge, and a diminution of water to effect the object?—Certainly.

Was it not a request from the Trial Works Committee to carry these experiments out further?—I believe it was.

Were they continued after the change in the Commission?—They ceased on the retirement of the late Commission; and a few days after the resignation of the consulting engineer I had directions to discontinue the experiments, and discharge the men employed on them.

By whose orders?—Those of the chief surveyor, Mr. Phillips.

At the highest ordinary storm rainfall, what extent of roof would a 3-inch pipe and 4-inch pipe respectively keep clear?—Taking the rainfall to be two inches in one hour, a 3-inch pipe, laid at an inclination of 1 in 60, would convey away the water from 47 squares of roofing = 4700 square feet; a 4-inch pipe under the same circumstances would carry off the rainfall from 98 squares of roofing = 9800 square feet.

The rate of house-drainage which it has been calculated can be removed in three minutes would of course be spread over the 12 hours?—Yes, over the day.

Consequently, for all purposes of soil-water, the size of drain might still further be reduced, and the flow of water required to keep them clear might be further economized?—Yes, as regards the sewage, but provision must be made for the passage of a certain amount of solid matter; therefore no drain should be *less* than *four inches* diameter.

Have you seen the 4-inch tubular pipes in various circumstances?—Yes; and I have found that they keep themselves clear; that is, where care has been taken in laying them down, and an uninterrupted outlet

Mr. [...]lworth. is provided; unless, through the carelessness of the occupier, substances that ought not to find their way into house-drains are thrown down the water-closet. A case of an obstructed house-drain occurred at one of my own houses within the last few days. The tenant complained that the water, &c., would not leave the closet and sinks. Upon making an examination by taking up the pan and trap, the latter was found to contain several *oyster-shells* (which certainly cannot be considered as legitimate deposit). One had been discharged into the drain, and was arrested by an irregular and imperfectly formed joint; it had thus become a nucleus for further obstruction, and ultimately by a piece of house-flannel, had permanently stopped the passage of the soil, &c. It is from such-like circumstances that prejudices arise against the adoption of a 4-inch drain. The above case would not cause me to alter my opinion as to the efficiency of a 4-inch drain.

Would a 3-inch pipe take more than the house-drainage?—Yes, considerably more *fluid* than belongs to the house; but I would not advise less than 4-inch tubes to be laid down for house-drains, as all the experiments tried seem to be in favour of a 4-inch pipe. In the 3-inch pipe the area is too confined to pass solids, such as large pieces of paper, &c.; and in a 6-inch pipe the water is spread over too extended an area. After four inches the area of friction increases so rapidly as to make it inexpedient to use larger pipes.

Taking a house-drain and its junctions, will you state within what time water discharged through it would get beyond the three-mile radius from the Post-Office, calculating with ordinary falls and levels, and the usual rate of discharge?—Suppose the house-drain to be of non-absorbent stoneware, the soil and slops from a house would leave the premises as fast as made; this, delivered into a main line of the same material and 12 inches diameter, laid with a fall of 1 in 240, and running full, would deliver the house-drainage beyond the limits specified in 45 minutes, the velocity of the stream in the main line being about four miles per hour.

Since by back-drainage you save two-thirds of the distance of discharge on an average, you increase the power as respects the velocity and friction?—Yes.

And you gain in that way in any escape that might otherwise occur of any of the gas from the decomposing matter?—Yes; in a well-constructed drain of stoneware no substances would remain to become decomposed.

With a system of tubular drainage where nothing is allowed to remain to decompose, a total alteration in respect to the smells and nuisances from such a source may, of course, then, be expected?—Certainly.

It has been stated that, in the case of new blocks of houses where tubular drains have been laid down, no offensive smells are found to exist; does that agree with your experience?—It does, where sufficient care is taken in the construction, and there is a supply of water to remove the contents.

Have you made any other experiments than those contained in the Trial Works Report?—Yes; the experiments in the King's Scholars' Pond Sewer were made by me. The tables and diagrams that I now submit to the Board are deductions and calculations made by me from those experiments.

Did you in those experiments register the velocity per second of the water?—Yes; by timing a floating body of nearly the same specific gravity as the water. Mr. Medworth.

Did you measure the velocity at the bottom or middle, as well as that of the surface?—No.

What is the hydraulic mean depth of a 3-inch, 4-inch, 6-inch, and 9-inch pipe respectively, when half-full?—The hydraulic mean depth in the 3-inch pipe is ·749, in the 4-inch pipe 1·, in the 6-inch pipe 1·5, in the 9-inch pipe 2·18 inches.

What is the amount of friction to be ascribed to those pipes respectively?—The frictional line, or line in contact with the water, when the pipes are half full would be—in the 3-inch pipe 4·71, in the 4-inch pipe 6·28, in the 6-inch pipe 9·42, in the 9-inch pipe 14·13 inches.

What must be the major and minor axes of an ellipse which shall give an equivalent hydraulic depth to that of a 3-inch, 4-inch, 6-inch, and 9-inch pipe?—

Drains, inches in diameter.	Axes of Ellipse.	
	Major. Inches.	Minor. Inches.
3	3·6	2·5
4	4·6	3·5
6	6·8	5·3
9	10·4	7·8

What amount of friction would be due to each of those elliptical sections?

In the 3-inch pipe	9·74	inches nearly.
„ 4-inch „	12·85	
„ 6-inch „	19·13	
„ 9-inch „	28·9	

Did you make any experiments on the flow of water in egg-shaped pipes?—No.

Can you institute any comparison between egg-shaped and circular drains, using, as a term of comparison, either "time of discharge," "quantity discharged," "friction," or "velocity?"—Not from actual experiment.

Have you any explanation to offer on the phenomena marked in page 6 of the Trial Works Report, relative to the power of transport of a gallon of water through a 3, 4, and 6 inch pipe?—This and other questions having reference to the opinions or statements contained in the "Trial Works Report," I do not think I should be justified in offering any remarks upon, as, in my capacity as Superintendent to the "Trial Works Committee," I was only engaged in *making* the *experiments*, *calculating quantities*, and *projecting* the *diagrams*. The deductions from these and the Report itself exclusively belongs to the "Trial Works Committee," who framed that Report.

Mr. Medworth.

Were the pipes of the same length, inclination, charged with the same head of water, and was the velocity at the exit equal?—They were equal in length, inclination, and charged with the same quantity —1 gallon of water; the velocity was not equal, being dependent upon the resistance offered by the deposit.

Supposing the impediment to be removed equal in weight, what head of water would be required for a 3, 4, and 6 inch pipe respectively?—Experiments would be required to determine the point involved in this question.

To what velocity does that level correspond; that is to say, supposing no impediment to exist, what would be the velocity of the fluid at its exit from each pipe charged with those heads of water respectively?—No experiments have been tried which will enable me to speak to this point.

Did you find the power of transport of a cube foot of water in a 3, 4, or 6 inch pipe bore the same ratio, supposing the inclination to vary? Or did this phenomenon occur only at one particular inclination? —It was only tried at one inclination. A reference to the diagram No. 2 will show the arrangement of this experiment.

How did you explain the remarkable fact then; an inclination beyond 1 in 60 offers far less advantage than has been commonly attributed to it?—I should be unwilling to offer an opinion upon this fact, as it has been specially noticed by the Trial Works Committee, though not explained by them.

Have you the results deduced from the experiments in the Fleet Sewer?—I have not.

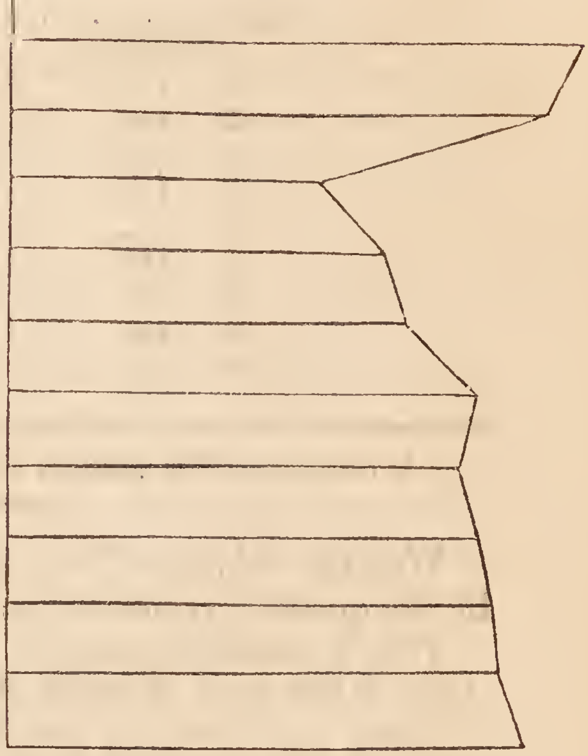
Did you find the length of the tube made any difference in the velocity?—In very many of the experiments at Greek-street I noted the time that a floating body was passing half the length of the tube (50 feet), and again at the end; but the total length (100 feet) was not sufficient to enable me to perceive any appreciable difference.

At page 20 you have given an ideal section of the flow in a pipe; have you any such sections from actual observation?—The papers Nos. 6 and 1 contain various diagrams showing the sections of the flow in pipes of different areas, and under varying conditions. The sections I now hand in are from actual observations; nearly all the experiments I made can be projected in the like manner.

You say that each tributary adds something to the velocity of the main, yet the addition is gradually less; what ratio does the *decrease* follow?—The ratio of increase or decrease is dependent upon the inclination, also upon the position of the tributaries on the main line. Referring to the case of a line of pipes of 4 inches diameter, laid at an inclination of 1 in 240, with junctions each 3 inches diameter, it will be seen by the subjoined table (page 209), that the velocity due to the main stream is but little altered by the addition of No. 1 Junction (the section is *increased*, and, consequently, the discharge). But upon the introduction of two junctions the main line becomes filled, and the velocity is decreased one-third; from this point the decrease gradually becomes less, but to what extent the experiments did not reach.

Mr. Medworth

TABLE showing the Velocities; the Sectional Areas; and the Discharges of the Flow through a Main Line of Pipes 4 inches diameter by the introduction of Tributaries, each 3 inches diameter, and running in the following order:—

Main Line and Junctions.	Distance of Junctions from Head of Main Line.	Mean Velocity in Feet per Second.	Section in Inches.	Discharge in Cubic Feet.	Diagram illustrating Velocity.
	Feet.				
Main Line.	..	3·5	..	9·3	
1. Junction.	5	3·3	0·58	9·67	
2. Do.	25	1·9	6·56	10·16	
3. Do.	45	2·3	6·56	12·17	
4. Do.	65	2·5	6·56	13·33	
5. Do.	85	2·9	6·56	15·47	
6. Do.	10	2·8	6·56	14·93	
7. Do.	30	2·9	6·56	15·39	
8. Do.	50	3·05	6·56	15·8	
9. Do.	70	3·09	6·56	16·15	
10. Do.	90	3·2	6·56	17·12	

At what point would the water be dammed up in the tributary channels by the rapidly flowing water in the main, that is, after how many junctions had been made?—An inspection of the diagrams Nos. 3, 4, 5, will in some measure illustrate this question; it would appear that at an inclination of 1 in 240 before the introduction of any junctions, the water is backed up in the junctions, owing to the flow in the main line. There is no experiment to show the point at which the water would be dammed up in the tributary channels by the water in the main.

You have found the present experiments too restricted to ascertain the limits of velocity and distance; will you favour the Board with an idea of the scale on which you would require to try these experiments, in order to acquire sufficient data to enable you to lay down a theory on this subject?—The experiments have been far too restricted to enable any theory to be laid down on the subject; they would require to be made with pipes and channels of various forms, of large dimensions, and various lengths.

What, approximatively, judging from past experience, would be the cost of such a series of experiments?—The cost can only be ascertained from knowing to what extent the late Committee would consider it necessary to carry them.

The table, page 26, gives the increased discharge for each additional junction; what was the difference of velocity at the outlet when 1, 2, 3—10 junctions were added?—I have no sections of these experiments of this size from which I can calculate the velocities but

Mr. Medworth.

the following, from experiments with the 4-inch pipes, which will give some idea of the principle of increase:—

MAIN LINE 100 feet in Length, 4 inches Diameter; the Junctions on to Main Line 3 inches each Diameter; Inclination 1 in 10.

Main and Number of Junction.	Distance of Junctions from Head of Main Influent.	Mean Velocity in Feet per Second.
	Feet.	
Main. . . .	. .	8
1. Junction.	5	9
2. Do.	25	10
3. Do.	45	12
4. Do.	65	9
5. Do.	85	10
*6. Do.	10	8
7. Do.	30	8
8. Do.	50	9
9. Do.	70	11
10. Do.	90	12

* A reference to the position of the junction on the main line will explain the cause of the diminution.

Was the velocity of the influent constant or variable?—Constant, if by the question is meant the head of water at the influent.

Was it constant among all the influents of the same system?—Constant, if the head of water at the inlets is meant.

Have you seen an article in the 'Mechanics' Magazine' for 9th December, 1849, signed J. L. Hale?—I have; it was pointed out to me at the time. The *deductions* and *calculations* are my own, and were submitted by me to Mr. Hale (in his capacity as an officer of the Commission) for his opinion, and for the purpose of checking the calculations, as it was my intention (at that time) to lay the same before the Court.

Is the statement correct that the squares of the discharge are as the fifth powers of the diameter; and that in inclinations greater than 1 in 70 the discharges are as the square roots of the inclinations?—The calculation that I made at the time was, that the discharges of pipes of different diameters vary as the square root of the quotient of the fifth power of the greater diameter, divided by the fifth power of the lesser diameter, multiplied by the known discharge of the smaller pipe. The ratio of discharge due to greater inclinations than 1 in 70 is as the square root of the inclination. These deductions I arrived at from and after a careful investigation of the results found by the experiments. Mr. Hale, writing without data before him, is in error in respect to the "simple head of 22 inches" giving the same result as that "accruing under the circumstances of the junctions," as is shown by the diagram of the discharge through a 6-inch pipe, with increasing heads: about 14 inches head (above the centre of the pipe) will give an equivalent result. It is in the case of a 4-inch pipe that a "head of 22 inches" has been found to correspond with the results from junctions.

Will you throw some of your results into a tabular form, illustrating by the method of ordinates and abscissæ the results set forth in Mr. Hale's paper?—The diagrams now produced are copies of the original ones projected by me. (See No. 1.)

Mr. Medworth.

Have you made any experiments on the influence of material of the pipes in accelerating or retarding the flow?—A partial experiment was tried at Greek-street; the pipes used were red ware and glazed stoneware, each 3 inches diameter. The velocity was much greater in the glazed stoneware pipes.

Did you register atmospheric temperatures and pressures during your experiments?—I did not.

Was the same watch employed throughout all the experiments?—It was.

Was it day by day compared with a standard regulator?—No.

Can you indicate any disturbing forces as probable causes of error in any of your experiments?—Whenever any material discrepancy occurred it would be in consequence of the difficulty in maintaining the precise head of water at the inlet. In all such cases the observations were carefully repeated.

Have you any remarks to offer on the general character of your experiments?—I consider them to be practically correct. Nothing approaching to mathematical accuracy could of course be expected to be arrived at in this series of experiments, but I consider they will supply sufficient data (as far as they go) for all practical purposes.

What further experiments do you think it would be desirable to make?—Full experiments were tried with pipes ranging only up to 6 inches diameter, and partially, only, with pipes ranging from 6 to 12 inches diameter. It would be exceedingly desirable that these experiments should be extended up to the very largest sizes, and varied in every possible way, so that safe and practical rules might be arrived at for the larger classes of sewers, without having to resort to formulæ based upon the result of experiments with tubes of small diameter.

Will you furnish the Board with drawings of your apparatus and account of the cost of the whole detail?—The cost of the experiments I have no means of ascertaining; the secretary alone can answer this the question.

You have observed the action of small 4-inch tubular house-drains; do you find it necessary in practice, for cleanliness and efficiency, to keep such drains constantly running, or flushed out at frequent periods, to prevent the hardening of deposit? Have you found any tendency to deposit in them with the present supply of water?—I have in numerous cases observed small tubular drains which have acted and continue to act perfectly, with the ordinary supply of water. I have not found that the water is required constantly to run through them, or that they require frequently flushing. There is no tendency to deposit in them, the ordinary supply of water keeping them perfectly clean. In these cases there was *a free outlet*, the tubes were *properly* laid down, and no *impediment* at the *joints*. I would further remark that, upon all occasions where I have been able to investigate the cause of obstruction in a small drain, I have invariably found it to proceed from substances such as shells, broken earthenware, sticks, &c., becoming fixed at the sock-joints; this soon forms a complete dam across the tube, and the drain is choked; and no ordinary power or quantity of water that could be sent down by flushing would be sufficiently effective to remove the compact mass; the only method to relieve it is by breaking up the drain. I would strongly recommend the use of pipes conical at the end, the *end* of the one pipe

Mr. Medworth.

going into the *head* of the *other*; here the liability of stoppage is all but impossible.

Take the case of a large brick drain at the same inclination as the small tubular drain, what do you find in practice?—In the large brick drain I find as the result deposit constantly accumulating, which the ordinary supplies of water are wholly inadequate to prevent. The water that does not escape through the open or imperfectly made joints of the brickwork is rendered almost inoperative by being spread over a large area.

Then the inference is, that with the present supply of water the small tubular drain would be self-acting, and that the large brick drain would require a constant flushing power to remove the accumulated deposit?—Yes, such would undoubtedly be the case; as the house-drains, where there is a water-closet attached, are periodically under the influence of flushing, by the use of the closet and the emptying of slops in the course of the day. On washing-days sudden rushes of water thrown down the sinks furnish a very powerful means of flushing and removing obstructions; and every shower of rain, where the stack-pipes are judiciously placed in reference to the house-drains, is a powerful concomitant to the efficiency of a *non-absorbent* tubular system of drainage, in which not the least quantity of water that finds its way into the drain will be uselessly expended.

It is clear to you then that the small tubular system of drainage will require a much less quantity of water than is required for the existing system of brick drains?—Yes, quite so. In practice we invariably find such to be the case; as in the tubular system the whole of the water that is sent down the drain would be brought to act upon the deposit, which would be suspended, and thus prevented from accumulating; on the contrary, in brick drains very little of the fluid finds its way to the outlet of the drain into the sewer, being absorbed by the material of which the drain is composed—generally of place (or imperfectly burnt) bricks—or percolating through the numerous open joints of the brickwork, leaving the more solid portion of the sewage to become indurated, and ultimately to choke the drain.

Mr. William Baddeley.

Mr. Baddeley.

1. You are, I believe, an engineer?—Yes, and for four years I have been Inspector to the Society for the Protection of Life from Fire.

2. Then you have attended many fires?—I do constantly, and have done so for the last 30 years. I have given a great deal of consideration to the subject of water supply at fires during the last 30 years, and have been in early attendance at all the principal fires in the metropolis during that period.

3. Between the time of alarm of fire being given, and a brigade engine being brought to bear, what time, with the present arrangement, elapses before the engine is on the spot?—At Islington, where I reside, the time might be about 40 minutes; but in the City, where the stations are closer together, the time would be, I should say, from 15 to 20 minutes; there would be 3 minutes for mustering the policemen, and the engine-station would be, say 10 minutes off; in 5 or 6 minutes the engine would be got out, and then 5 minutes would elapse before it

was on the spot. The turncock is most probably on the spot first, so that 23 minutes altogether would be a fair average time in any district. Mr. Medworth.

4. What proportion of fires do you think might be avoided by the adoption of efficient means?—The number of fires last year was 838; and if there had been the means of applying water immediately, two-thirds of them would have been stopped immediately.

5. Would you say that the means of applying water in adequate quantity within 5 minutes of the commencement of a fire would prevent the progress of two-thirds of them?—Yes, about that time.

6. In some places has not delay occurred from the turncocks being at wide intervals?—Yes, on the south side of the Thames particularly. It is generally objected by the Companies that none but their own servants shall have command of the main-cocks in order to prevent confusion, as though it is necessary to have one or two cocks open, it is necessary to close two or three others to get the supply of water at the required spot.

7. Under a high pressure system of course there would be a much stronger jet given than can be procured by an engine?—Yes, certainly.

8. And you think, with such an apparatus, that two-thirds of the fires might be stopped?—Yes, they might be stopped immediately.

9. Then, from your experience, you have no doubt that the prompt application of water would be most beneficial?—I have no doubt whatever.

10. And should there not be an inquiry also afterwards?—Yes, a subsequent inquiry is most useful.

(The witness is here shown the evidence of Mr. Lindley, as to the efficacy of the constant supply of water in putting an end to fires, and states, that he quite agrees as to the important effects of such a supply in this respect.)

11. Does not the fire brigade prove as efficient as all the rest of the assistance at fires put together?—Certainly.

12. Have you not been so much impressed with the importance of an immediate application of water that you have invented various engines to promote it?—I have. The usual sizes of the brigade jet pipes run from three-fourths to seven-eighths of an inch, and the quantity of water delivered, about 90 gallons per minute. When the fire is raging in warehouses, or other buildings of great extent, even this size, or larger jets, may be used with advantage, but in the earliest stages of a fire a very much smaller quantity applied, so as to cover an extensive surface at once, is infinitely more useful in extinguishing the fire, while the damage done by the water is kept at a minimum. The truthfulness of this principle has long been established in the minds of scientific men, but little progress has been made in its practical application. Although the engines of the London Fire Establishment have the convenience of attaching two distinct lines of hose, none of them, that I am aware of, carry smaller nose pipes for that purpose, so that where a fire requires to be met at two points, the front and rear of a building for instance, two engines are constantly employed, thus throwing in 180 gallons of water per minute, whereas even 90 gallons would have been more than enough if judiciously applied. Water applied in a form of a jet is frequently unsuited to the character of a fire, as in the case of hay and

Mr. Baddeley. other stacks, large surfaces of weather boarding, and such like matters, where a large burning surface requires to be covered and extinguished, but where there is no mass of fire to be dealt with; in these cases the jet is inapplicable. In order to render a *small* quantity of water effectual in extinguishing burning surfaces of considerable extent, I invented a *spreader* to be applied to the nose-pipe, kept back out of the way of the jet by a spring, until the thumb was pressed upon a lever, which brought a fan-shaped spreader over the jet, which became broken up, so as to cover a very large space. This invention was registered, agreeably to Act of Parliament, in May 1842, and Mr. Merryweather, fire-engine manufacturer of Long-acre, London, was licensed to manufacture and sell them. These *spreaders* have been used in agricultural districts with great success.

The fire police of Liverpool, Manchester, and Sunderland, have long used them; but the London Fire Establishment, with their usual apathy towards inventions not originating with themselves, have *not adopted* this useful contrivance. In February 1849, I made a considerable improvement in the *spreader*, of which Messrs. Warner and Sons, Jewin-crescent, became the purchasers, and it was registered in their name, and as applied to garden and fire engines, is coming into very extensive employment. In carrying out my convictions of the efficacy of small supplies of water, judiciously applied for extinguishing fire, in 1847, I designed a farmer's fire-engine, well adapted in all respects to give effect to these intentions. In the beginning of 1848 I constructed a portable fire-engine adapted for domestic use, calculated for the working of one man, to be put into a pail or bucket, and furnished with a length of hose, branch pipe, and spreader, so that in all cases of fire, in a single apartment, one pail of water thus applied would suffice for the extinction of the flames. A German, some years ago, showed that a large burning surface could be effectually covered with a small quantity of water, and it has been my object to carry that idea efficiently into practice. Of the 838 fires in the metropolis, in 1849, I calculate that two-thirds might have been extinguished by the prompt application of my portable fire-engine by the inmates themselves, and that the same apparatus in *experienced* hands would have sufficed for the extinction of *three-fourths* of last year's fires. A small hand-pump of less power than mine has been used by the London Fire Establishment during the last 12 months as an auxiliary to the fire-engines rather than as a substitute for them; these hand-pumps, however, have proved very useful, and it is to be hoped their sphere of usefulness will be yet further extended. Without a *spreader*, however, they lose more than half their efficacy.

13. On the whole you concur with the evidence which has been given that a constant supply of water would diminish the number of fires?—It would diminish them, not in number but in extent, and it might tend to check the number of incendiary fires. It is difficult to imagine any provision by which the occurrence of fires will be prevented, but every improvement which renders dwellings less combustible and more fire-proof, which shortens the time of bringing remedial measures to bear upon the destructive element, or increases their efficiency, must materially reduce the extent of damage by fire. Even if unaccompanied with other amendments, the use of incombustible stairs in our buildings,

and the supply of water under pressure being constant, would be of immense benefit in checking the spread of accidental and wilful fires. Mr. Baddeley.

14. Besides the increased chance of fires being extinguished from the immediate application of water, would there not also be a benefit from the decreased damage resulting from the use of a smaller quantity of water?—The amount of damage from water is now unnecessarily large.

15. What were the proportions of the total losses at last year's fires?—The total number of losses last year amounted to 30 out of the 838 fires. In more than 200, the contents of the buildings were very seriously damaged. It sometimes happens that the damage by fire is very small, and the damage by water very large.

16. Would it not be a great advantage that the police should have keys, so as to get at once at the water?—They are the only parties who could give efficiency to a system of this sort.

17. Of course, diminishing serious fires two-thirds in number would diminish the general risk in the same proportion?—It would diminish the risk in a still greater proportion.

18. Do you not find, from your experience, that an apparatus kept for extraordinary events is seldom kept in good order, or in a state of readiness?—Such is certainly the case.

19. And, therefore, it would be of great advantage if the apparatus, which would be of service in the case of fires, were otherwise kept in constant use?—Yes, and by that means the persons who would have charge of it would become familiarized with the use of it.

(The Witness gave in the following tables.)

TABULAR EPITOME of METROPOLITAN FIRES, from 1833 to 1849. By W. BADDELEY, 29, Alfred-street, Islington.

YEARS.	Slightly damaged.	Seriously damaged.	Totally destroyed.	Total Number of Fires.	False Alarms.	Alarms from Chimneys on Fire.	Total Number of Calls.	Insurances			
								On Building & Contents.	On Building only.	On Contents only.	Uninsured.
1833	292	135	31	458	59	75	592	..	..	..	..
1834	338	116	28	482	63	106	651	..	..	..	..
1835	315	125	31	471	66	106	643	..	..	..	..
1836	397	134	33	564	66	126	756	169	73	104	218
1837	357	122	22	501	89	127	717	173	47	76	205
1838	383	152	33	568	80	107	755	161	59	128	220
1839	402	165	17	584	70	101	755	169	58	115	242
1840	451	204	26	681	84	98	863	237	92	104	248
1841	438	234	24	696	67	92	855	343	149	52	152
1842	521	224	24	769	61	82	912	321	116	112	220
1843	489	231	29	749	79	83	911	276	124	107	242
1844	502	237	23	762	70	94	926	313	138	94	217
1845	431	244	32	707	81	87	875	313	107	73	214
1846	576	238	20	834	119	69	1,022	302	137	125	270
1847	536	273	27	836	88	66	990	263	125	157	291
1848	509	269	27	805	120	86	1,011	310	120	134	241
1849	582	228	28	838	76	89	1,003	368	163	72	235
Total .	6,574	2,955	365	9,894	1,150	1,307	12,351	3,718	1,508	1,453	3,215
Average	470	211	26	770	82	94	882	266	108	104	230

ABSTRACT of CAUSES of FIRE in the METROPOLIS, from 1833 to 1849, inclusive.
Compiled by W. Baddeley.

YEARS.	Accidents of various kinds, for the most part unavoidable.	Apparel ignited on the person.	Candles, various accidents with.	Carelessness, palpable instances of.	Children playing with fire or candles.	Drunkenness.	Fire-heat, application of to various hazardous manufacturing processes.	Fire-sparks.	Fireworks.	Fires kindled on hearths and other improper places.	Flues foul, defective, &c.	Fumigation, incautious.	Furnaces, kilns, &c., defective or overheated.	Gas.	Gunpowder.
1833	83	.	56	28	.	.	31	.	.	7	71	.	.	20	3
1834	40	.	146	.	.	2	24	.	.	.	65	3	11	25	3
1835	14	.	110	19	5	3	39	.	3	9	69	7	2	39	.
1836	13	7	157	18	6	.	34	7	.	5	72	5	9	38	1
1837	17	7	125	7	18	2	22	10	5	5	53	2	12	31	3
1838	36	5	132	17	5	4	40	12	3	15	58	1	15	42	1
1839	25	3	128	14	12	6	26	9	5	8	58	5	20	72	2
1840	26	12	169	24	21	5	29	17	1	7	89	3	15	48	.
1841	26	5	184	25	18	5	16	13	4	8	83	2	12	48	.
1842	44	9	189	19	16	11	36	23	7	9	90	2	23	52	3
1843	19	5	166	27	20	6	14	17	5	9	105	1	19	40	1
1844	11	4	205	15	23	9	21	27	3	8	84	1	17	33	.
1845	17	3	165	14	19	7	22	24	10	12	78	3	29	54	1
1846	29	3	229	15	25	9	25	32	9	7	86	4	28	53	.
1847	20	3	237	20	16	5	16	65	6	3	78	4	14	63	2
1848	19	1	237	23	19	3	22	63	1	4	56	4	16	65	.
1849	13	2	241	24	15	7	23	40	8	4	78	2	21	57	2
Total	452	69	2,876	309	238	84	440	359	70	120	1,273	49	263	780	22
Average	27	4	169	18	14	5	26	21	4	7	75	3	16	46	$1\frac{1}{3}$

YEARS.	Hearths, defective, &c.	Hot cinders put away.	Lamps.	Lime, slaking of.	Linen, drying, airing, &c.	Lucifer matches.	Ovens.	Reading, working, or smoking in bed.	Shavings, loose, ignited.	Spontaneous combustion.	Stoves, defective, overheated, &c.	Tobacco smoking.	Suspicious.	Wilful.	Unknown.	Total.
1833	.	.	.	.	.	.	6	.	.	7	18	.	.	3	125	458
1834	.	.	.	3	.	.	.	3	6	2	20	6	.	9	114	482
1835	.	.	.	4	22	.	.	.	9	5	11	4	.	6	91	471
1836	.	.	2	3	31	.	6	.	13	4	28	1	.	8	96	564
1837	.	.	3	.	48	8	3	.	8	4	36	3	7	5	57	501
1838	.	.	9	4	32	9	11	1	17	5	31	4	8	6	45	568
1839	.	.	4	2	26	17	4	2	8	13	24	11	6	7	67	584
1840	.	.	3	2	25	18	13	.	27	11	48	9	11	9	39	681
1841	.	.	5	5	27	16	13	5	35	22	54	22	7	13	23	696
1842	3	3	2	4	41	17	13	2	22	20	32	17	9	19	32	769
1843	5	3	2	2	33	14	10	3	31	23	58	14	16	21	60	749
1844	2	7	6	3	45	19	10	.	18	34	44	21	7	11	74	762
1845	.	10	11	9	30	12	8	.	25	19	51	19	9	14	32	707
1846	4	8	7	7	39	14	8	3	35	18	43	29	7	19	39	834
1847	3	9	2	5	34	9	8	1	37	15	37	18	17	17	72	836
1848	4	5	3	5	36	23	2	1	27	7	48	37	11	25	38	805
1849	3	11	17	3	40	12	2	1	21	19	43	24	10	19	76	838
Total	24	56	76	61	509	188	117	22	339	228	626	239	125	211	1,080	11,305
Average	$1\frac{1}{2}$	3	5	4	30	11	7	$1\frac{1}{3}$	20	13	37	14	7	12	63	665

Metropolitan Sewers.—Westminster, &c.

Lord Morpeth's Charge to the Jury.

Charge to the Jury (delivered by Lord Morpeth, M.P.), April 6, 1848.

Gentlemen of the Jury,

You are summoned here by virtue of a provision in the Statute of the 23rd of Henry VIII., which authorizes the Court "to inquire by the oaths of the honest and lawful men of the shire or shires, place or places, where defaults or annoyances be, as well within the liberties as without (by whom the truth may the rather be known), through whose default the said hurts and damages have happened, and who hath or holdeth any lands or tenements, or common of pasture, or profit of fishing, or hath or may have any hurt, loss, or disadvantage by any manner of means in the said places, as well near to the said dangers, lets and impediments, as inhabiting or dwelling thereabouts, by the said walls, ditches, banks, gutters, gotes, sewers, trenches and other the said impediments and annoyances."

At the time the Statute was passed, there were few or no valuations, for other purposes, available for the purposes of sewers'-rate; the works to be executed were more simple, and the properties to be charged fewer. The author of this Statute of Sewers could not have contemplated that it would ever fall to the men of the county to assess, in one single district, between fifty and sixty thousand individuals, or the owners of more than fifty thousand tenements, occupied by nearly half a million of population, having a rental of upwards of three millions sterling, comprising immense varieties of properties. This multitude of properties renders it impracticable for you, within any reasonable time, to make direct inspections and adjustments of that part of the Westminster Commission this day brought before you, called the Eastern Division of the Westminster Sewers, within which there are nearly 15,000 separate tenements, with a rental of about 800,000*l.*; and it is necessary to have recourse to some intermediate agency or assistance to guide your decisions. This assistance is afforded by the valuations of properties to the poor-rate.

From the absence of appeal, however imperfect this test may be, we must assume that the parties are satisfied with that valuation, and that it is the true one. All that remains to be done for your satisfaction, and to enable you to perform your duty, is to present to you evidence as to who are rated to the poor's rates, and at what amounts, from which you will determine who are the parties to be assessed to the sewers' rates. This evidence will be given to you, with whatsoever assistance you may require, by the officers of the Court.

Looking at the multitude and varieties of properties, you will perceive that, if you felt disposed to go through the whole and found your presentments on original valuations of them, with the little means of assistance which could be afforded to you, and giving you credit for a great extent and variety of knowledge, you would in all probability come to less satisfactory results than by taking the evidence of the poor's rates which will be submitted to you. And here it is right that you should be informed that the rates now required will be for the payment of old debts rather than the creation of new ones. The same is the case in other districts.

Since a jury of the men of the county was last convened, the dis-

Lord Morpeth's Charge to the Jury.

trict, for part of which you are acting, though still continuing separate in form, is practically consolidated under one set of Commissioners for the whole of the metropolis, with the exception of one part of the drainage area. The most important point in which the Westminster District now before you must be interested, is that which might be elicited by the question—

What has this consolidation, carried out by the Government, done for us?

To take as an illustration the last subject under the consideration of the Court of Sewers—namely, the establishment of paid officers—

It has given you a large increase of valuable service, without any increase, probably with much diminution of expense.

For the Westminster District there was formerly one Chief Clerk Mr. Hertslet, and one Chief Surveyor, Mr. Phillips—able and efficient, public officers, who are both retained for your service, whilst they are advanced to a higher sphere of duty, and to more satisfactory because more efficient service. But the improvement of drainage-works demands scientific appliances and various abilities. We have added to the engineering force, Mr. Austin, as a Consulting Engineer, who has long studied the subject of town improvement; and Mr. Roe, who, as Surveyor to the Holborn and Finsbury Divisions, took the earliest lead in the improvement of this branch of the public works. Adopting the recommendations of the Sanitary Commissioners, we have deemed the improvement of these works so important to the public health, and the proper performance of the service so needful, as to require undivided attention. We have considered that these services could not be properly attended to as incidents to private practice. We have, therefore, resolved that all salaried officers throughout the several Commissions shall, in this department at least, give their whole time to the public service, and shall be freed from private practice. We have, moreover, abolished per-centages on works executed. We have, moreover, abolished all fees.

In the surveyor's department, we have appointed as an Assistant Surveyor, Mr. G. Donaldson, who was specially conversant with land-drainage, to attend to the subject of the drainage of the low-lying and open marshy land within the district, by which the sanitary condition of the covered district adjoining is affected. Having observed talent in the report of a Surveyor to the Paving Board of St. Andrew's Holborn, and St. George the Martyr, and evidence of special acquaintance with the subject of house-drainage, we have engaged that surveyor, Mr. Lovick, as an assistant surveyor in this service.

Mr. Stable, the highly-respectable Clerk of the Holborn and Finsbury Division, we have engaged to take special charge of the collections and disbursements of the rates. We also availed ourselves of the services of Mr. Grey, a public accountant, to systematise the accounts, and to enable us to throw light on the pecuniary branch of the administration.

By the consolidation, you have gained the additional services of one Chief Clerk, of a Consulting Engineer, and one Chief Surveyor, and two Assistant Surveyors, without any increase of expense to the Westminster District. The establishments and the payments are not yet fixed; but to the whole of the districts in the metropolis the consolida-

tion has been attended with this undoubted gain of service, with a reduced expense. The reduction in the surveying staff has already been from upwards of 6,000*l.* per annum for fragmentary and imperfect service, to 4,700*l.* for a consolidated and improved establishment. The gain to each of the other districts consolidated will be similar, and each has now available the services of the entire staff, and with a considerable reduction of expense.

Lord Morpeth's Charge to the Jury.

Secondly, you gain by the consolidation in all that efficiency of works which is dependent on systematic operations on a wide basis; or, in other words, you have had averted the worse than waste which is incurred by operations on a narrow basis, by feeble establishments acting on limited information.

When we entered upon our duties, the sewers of the district were, and unfortunately yet are, and with our best efforts are likely too long to continue to be, what your officers have described them to be—extended cesspools. We have had sewers in the same district running different ways; sewers made at great expense, which accumulate pestilential deposit (90,000 tons or 62,000 cubic yards of which we have had flushed away): all these works incurring waste of money for sewering the district ill, which would more than have sufficed not only to sewer it but to drain the houses well and abolish the pestilential cesspools over which they are built. Much of this waste has arisen from the want of a proper system of survey. The remedy for future works is to obtain a proper survey. This more perfect work, which will govern not only main drainage but house drainage, the better construction of streets, the better distribution of water, the identification of properties, better valuations, and the more equal collections of rates, increased efficiency or reduced expense of future works, you gain by consolidation.

One gain by the systematic works is, the better adaptation of sewers to the run of water which they are to discharge. That class of works has not yet been completely systematised. Until the survey which we propose to make is more advanced, we may not expect any new system of works to be completed. We have, however, in particular instances, and in cases of emergency, directed new sewers to be made. We may present as examples the new portions of Sewers brought under the consideration of the Court at the last General Court day, viz.:—

	£.	s.	d.
In Winchester-row, New Road.—An estimate for a 4-inch pipe even from each house, instead of a brick drain, as required under previous practice	171	8	4
Ditto for drain at back, instead of the new mode just mentioned	52	6	3

The second estimate was approved.

In Dean-street, Soho.—1,300 feet to 470*l.*, including junctions for house-drains, was ordered, for which the estimate in 1843 was 1,412*l.* without such junctions for house-drains.

In Bedfordbury, St. Martin's.—130 feet of sewer is to cost 33*l.*; in 1841, 190 feet at the lower end cost 278*l.* 5*s.* 5*d.*

Lord Morpeth's Charge to the Jury.

You may be aware how much of the suburban drainage consists of open ditches at the bottom of gardens. The following is one instance of this kind where an uncovered ditch of 10 or 12 feet wide was complained of as offensive:—

Gloucester-street, Shoreditch.—Estimate for 860 feet of pipe-drain in lieu of open ditch, 215*l.*; former estimate, 600*l.* Nearly a quarter of an acre will be recovered by filling up the ditch. A space of garden-ground, 10 or 12 feet wide, will be gained to each house as a flower-bed, in the place of a stagnant ditch.

The foregoing cases may be briefly stated as follows:—

	Old Plan.			New Plan.		
	£.	*s.*	*d.*	£.	*s.*	*d.*
Winchester-row, New Road .	171	0	0	52	0	0
Dean-street, Soho . .	1,463	0	0	470	0	0
Bedfordbury, St. Martin's .	200	0	0	33	0	0
Gloucester-street, Shoreditch	600	0	0	215	0	0

We have before us two reports for the future drainage of Westminster, comprehending varied applications of the similar principle. We may present an estimate from one, not because it is determined upon yet, but because it furnishes an exemplification on a larger scale of the economies to which we hope to approach,

The comparative cost of drainage-works formerly constructed, and of those now proposed on spaces equally covered would stand thus:—

Per lineal Mile.

	Annual Cost of Flushing, Cleansing, and Repairs.	Average rate of Principal and Interest per house, reckoning 320 houses per mile.		
	£.	£.	*s.*	*d.*
Expense of works as formerly constructed, 5,000*l.*	70	1	2	$2\frac{3}{4}$
	Annual Cost of Pumping and Maintenance. £.			
Expense of the system at present proposed, 1,000*l.*	25	0	5	

The proposed works costing less than one-fourth of the former system.

In respect to the more temporary operations of cleansing, we may mention, that at the contract price for cleansing under the old system, by the offensive mode of hand-labour and cartage, the expense would have been at per load (taking the sum paid by the city of London, and taking an average of the other districts), 7*s.*, or for 62,000 cubic yards, 21,700*l.*; while the actual cost under the new system, including every expense, has been 4,650*l.*

Lord Morpeth's Charge to the Jury.

We have endeavoured, as far as our powers would permit, to turn the principle of flushing to account for the relief of the poorer districts, and by the removal of the contents of cesspools by means of the pump and hose; and this we have accomplished at less than one-third of the cost, and without any of the usual offensive and injurious effects of the operation.

In respect to the management of the rates, besides reducing the collections we have not thought it of advantage to give to one great company (the Bank of England) the undivided profits on the balances of the rate-payers' money in our hands; but, having obtained freehold security from another banking company, and they having given, with greatly increased facilties for transacting business, interest at the rate of two per cent. per annum on the current balance, we have thought it right to open an account with them; and with this saving of interest we expect to pay the salary of two additional assistant surveyors at the least.

The gains from consolidation, then, are, the increase of the force of the establishment, the increase of the efficiency of the works, and a reduction of the expense.

Our future progress, we expect, will be in the increase of efficiency. The surveyors have at present under consideration improvements in house-drainage which we expect will be accompanied by similar reductions in expense concurrent with the improvements.

Further advances to the completion and perfection of the works and the administrative service must be dependent on the completion of the drainage district, and on the consolidation of other connected works within our present district, under one and the same competent management.

Had Westminster remained under a management separate from the other districts, effluvia arising from any deposit created by defective cleansing in this district would not only have been diffused in greater quantities than it yet is amidst your habitations, but if the sewers and drains within your own districts were perfectly well cleansed, you would still, on the prevalence of certain winds, be exposed to the miasma carried from the ill-cleansed sewers in other parts of the drainage area.

Your own position may be shown by contrast; but representations having been made that increased expenses would be consequent upon the consolidation, or what is termed the centralization, of our local institutions, at this time of real pressure it is important that the truth should be known, and what has been the fact, and that the course of real improvement is one of economy and of reduction of burthens. The sewers' rates have been, and might continue to be as they would be under separate management, worse than wasted. But sickness and disease, and premature disablement, not to speak of premature death, entail heavy pecuniary burthens, and all well-devised works, and carefully-applied expenditure, must be in diminution of some of the most serious burthens, and tend to give health and strength to meet others which may be less preventible. The rates now required will be confidently applied in reduction of those burthens. But an increase of efficiency in their application depends on the completeness of the powers given for the purpose. In respect to works, an estimate has been cited

Lord Morpeth's Charge to the Jury.

to show that a complete system of main sewerage may be expected for all Westminster at a charge not exceeding 5*s.* per house per annum, or little more than 1*d.* per week, for works more complete and certain than any which now exist.

When we are speaking of expenses, we must notice one item of reduction which we have felt it our duty to enforce. The Statute under which we act makes no provision for dinners, and we have discontinued that practice. If it were discretionary with us, we should not think it good policy to hold forth the pleasures of the table as an inducement to the service. In strict law, however, we have felt it our ungracious duty to disallow payments for dinner-bills of our predecessors to the amount of 186*l.* for the last two months they were in office. We take no dinners ourselves, and I fear, gentlemen, we can offer no public hospitality to you.

"On analysing the business of District Courts meeting weekly, fortnightly, monthly, or quarterly," say the Sanitary Commissioners in their First Report, "it appears that a large proportion of it arises from the very defects of their own plans and works, which under an amended system will disappear. Those who have paid attention to the despatch of large amounts of varied business, are aware that, up to certain limits, the larger the amounts, the more complete are the means of classifying and systematizing it, the better the real despatch of it. We would cite, as an example, the consolidation, under the Metropolitan Roads Commission, of the administration of the roads formerly administered by a number of local trusts, comprehending the suburban parishes in the metropolis. Under that Commission, the roads have been improved, the tolls and the debts reduced, and the business of 100 miles of road transacted satisfactorily, with less attendance and consumption of time on the part of the honorary members of the Board than was previously required, by the defective despatch of business, by any one of the numerous separate Boards under which important improvements were found to be impracticable. It may be averred that the business of a Commission of Sewers for the whole of the metropolis may eventually be despatched better and more expeditiously than the business of one of the single Commissions."

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